Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 FEBRUARY 1956

TEXAS TECHNO- CAL
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COLLEGE

Streamline diffusing discharge regulators

'ENGLISH ELECTRIC' cylindrical balanced discharge regulators destroy the energy contained in the discharge water from dam outlets and so prevent damage to the sides of the valley, river bed and concrete structure. These regulators are extremely compact. They are simply controlled—manually or by motor—and the balanced cylindrical piston ensures smooth closing under all conditions.

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hydro-electric equipment

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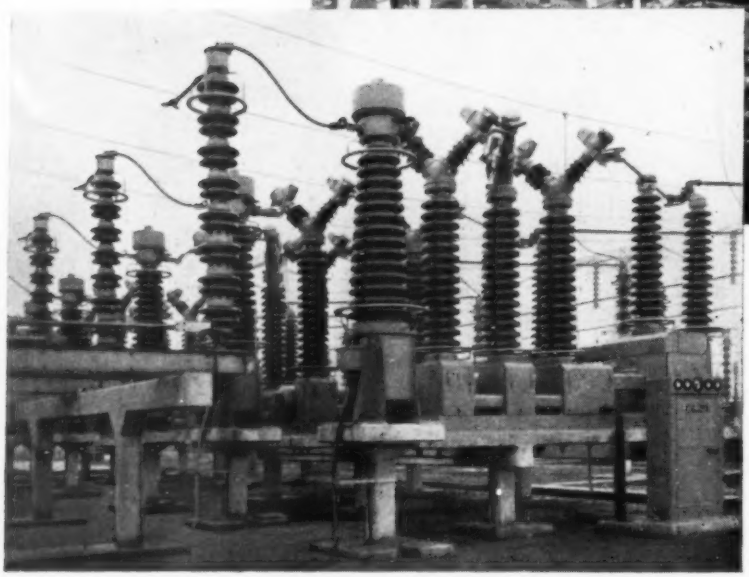
Hydro-electric Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON



CONSULTING ENGINEERS:
MESSRS. MERZ AND McLELLAN

Photographs by courtesy of the C.E.A., E. Midlands Division

Reyrolle 275-kV air-blast
circuit-breakers
now in commission
at DRAKELOW
power-station.

Electrical switchgear by

Reyrolle

A. Reyrolle & Company Limited · Hebburn · County Durham · England

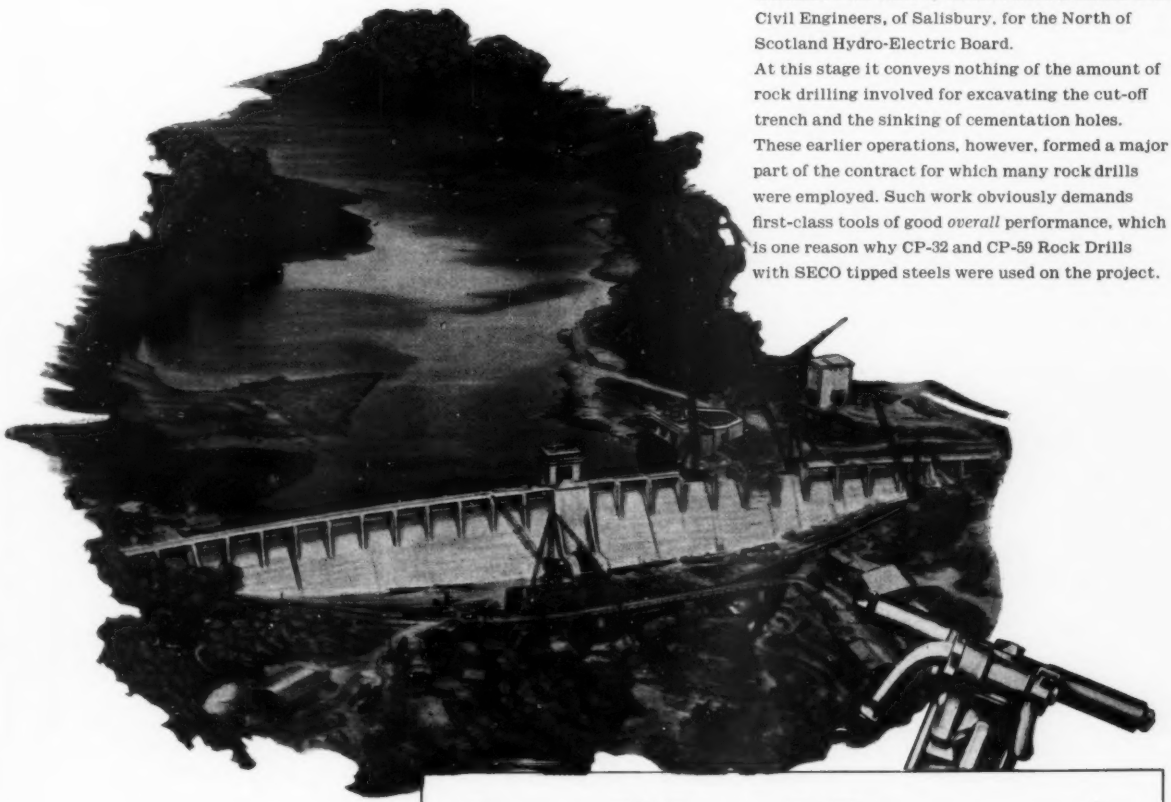
On the Conon Basin Project . . .

REED and MALLIK used

CP ROCK DRILLS to excavate the cut-off trench and drill cementation holes on the construction of the LUICHART DAM

This artist's impression drawn from an aerial photograph shows work nearing completion on the Luichart Dam built by Messrs. Reed & Mallik Ltd., Civil Engineers, of Salisbury, for the North of Scotland Hydro-Electric Board.

At this stage it conveys nothing of the amount of rock drilling involved for excavating the cut-off trench and the sinking of cementation holes. These earlier operations, however, formed a major part of the contract for which many rock drills were employed. Such work obviously demands first-class tools of good *overall* performance, which is one reason why CP-32 and CP-59 Rock Drills with SECO tipped steels were used on the project.



(Original photograph by courtesy of the North of Scotland Hydro-Electric Board)

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CANADIAN VICKERS LIMITED

in Association with:

MACHINENFABRIK AUGSBURG-NURNBERG A.G.

for the

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to be installed in the new

NIAGARA POWER DEVELOPMENT

For better Hydro-Electric Equipment . . . for jobs large or small . . . for use any place in the world, always consult—

CANADIAN VICKERS MONTREAL LIMITED

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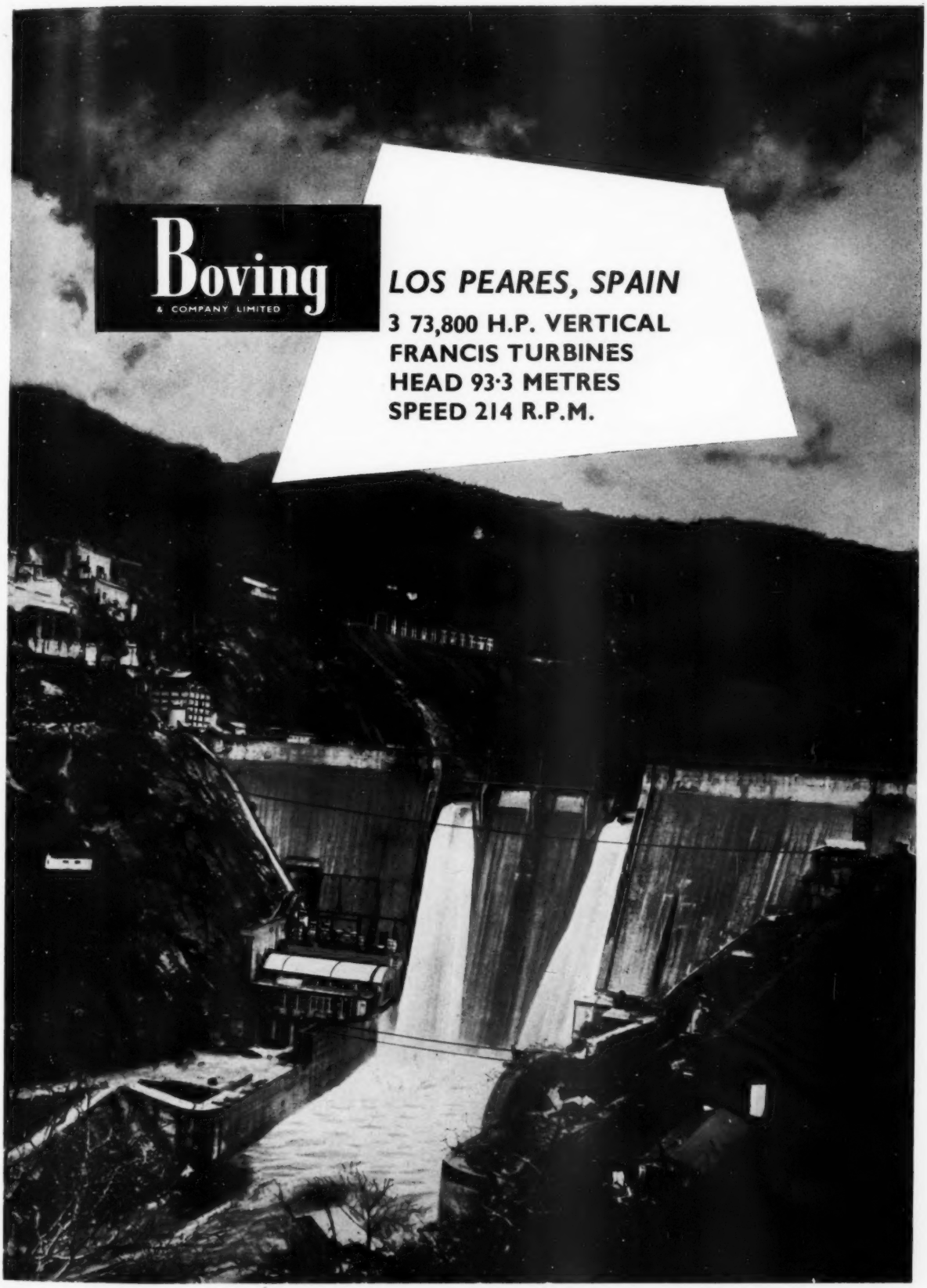
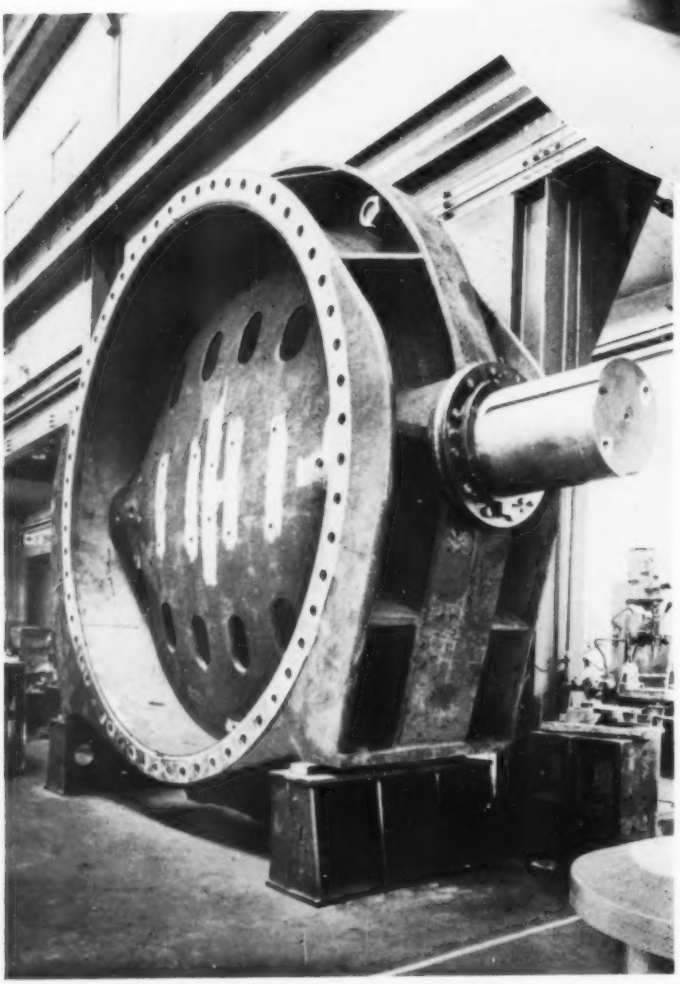


BOVING & COMPANY LIMITED WATER POWER ENGINEERS 56 KINGSWAY LONDON WC2 ENGLAND

P388

KMW
TURBINE VALVES



Above :

THE 59″ DIA. ROTARY VALVE

for the KMW Turbine installed in the Swedish Power Station of Tåsan in Värmland (turbine output: 48,200 H.P. at a head of 856 feet).

To the left :

THE 151″ DIA. BUTTERFLY VALVE

for one of the four KMW Turbines installed in the Spanish power station of San Esteban, belonging to the Saltos del Sil, S.A., Madrid (output of each turbine: 90,700 H.P. at a head of 338 feet).

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD

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Perfect below the surface

The medium weight Holman Silver Three — specially designed for use with the labour-saving Airleg — is helping to raise output and cut costs in mining and tunnelling projects all over the world. Fast-drilling, reliable, easy to handle, it has shown itself to be superior in design and construction to every other machine in its class.

Bore : 3″ (76 mm.)
Stroke : $1\frac{15}{16}$″ (49 mm.)
Weight : Dry, 47 lb. (21 kgs.)
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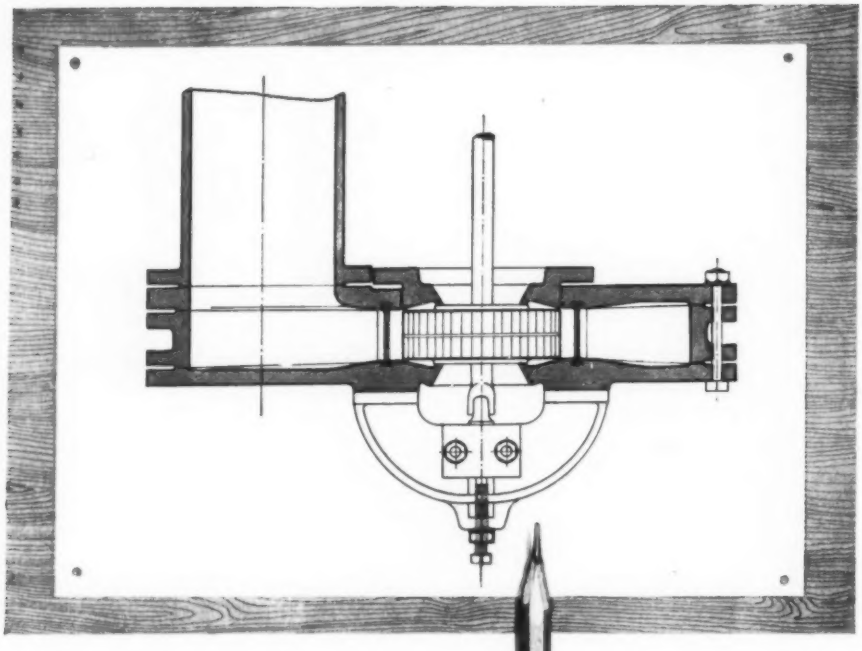
1856 - 1956



A dimensionless expression . . .

. . . of a century old determination to build better water turbines. This is a reproduction of one of the drawings of the first water turbine we built, in 1856 in our Works in Kendal. The drawings are beautifully executed and coloured, but have neither dimensions nor tolerances. Sizes were scaled from the drawing by the man on the job. The turbine, an advanced design in its day, is still at work driving machinery for Mr. John Robinson at Homescales, near Kendal. Using modern research and manufacturing techniques we build water turbines with outputs up to 10,000 B.H.P. which are shipped to all parts of the world. Our drawings are now dimensioned, but we admit no limit to our continued determination to serve the world well for another 100 years.

GILBERT GILKES & GORDON LTD

WATER TURBINE & PUMP MANUFACTURERS

KENDAL & LONDON . . . ENGLAND

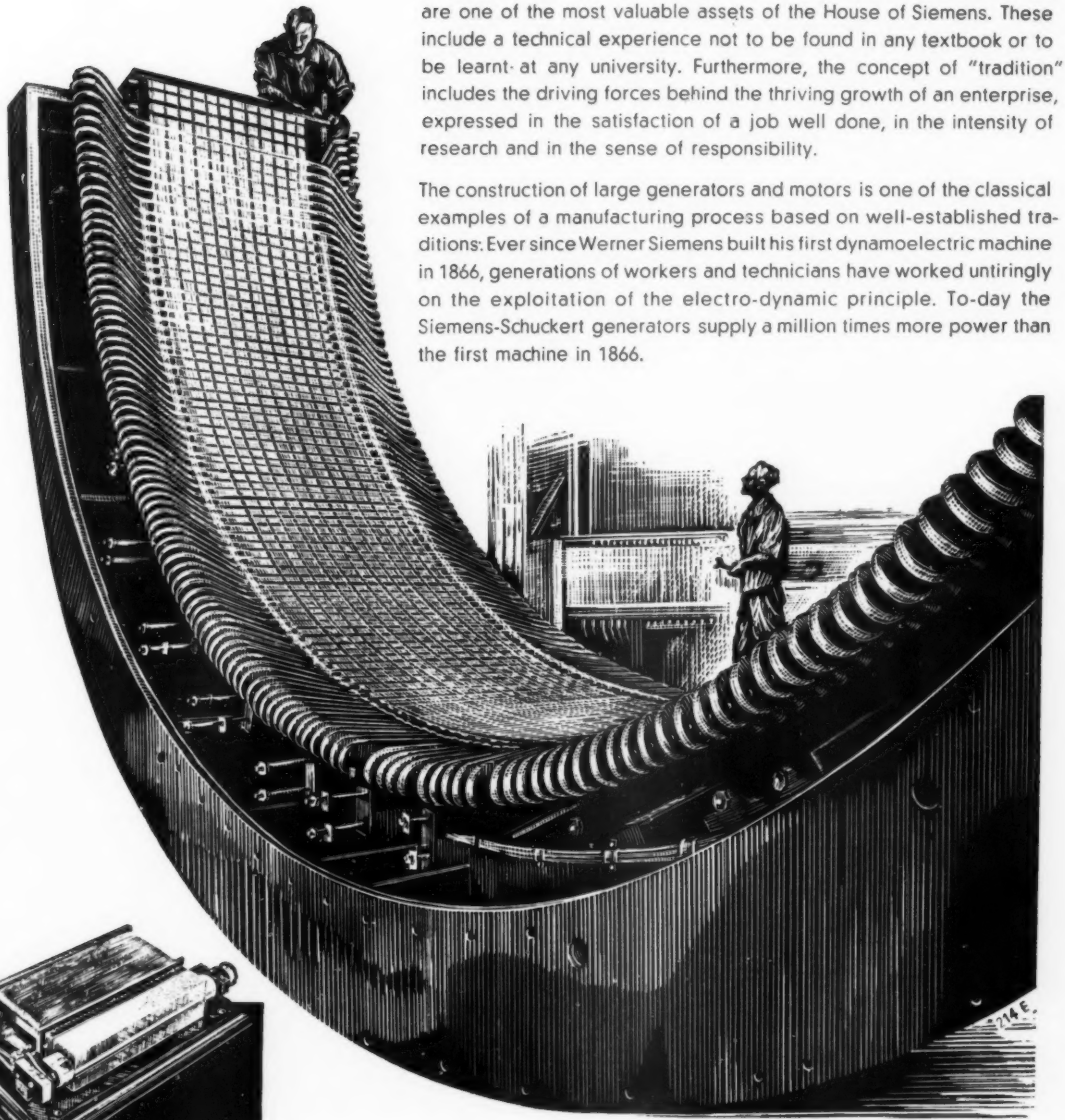
G67

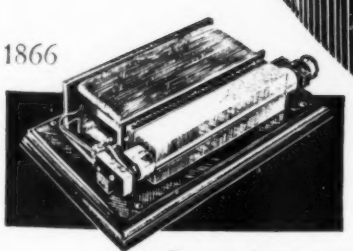
SIEMENS

Tradition - a living force

Sober statistics can never show the living forces of tradition which are one of the most valuable assets of the House of Siemens. These include a technical experience not to be found in any textbook or to be learnt at any university. Furthermore, the concept of "tradition" includes the driving forces behind the thriving growth of an enterprise, expressed in the satisfaction of a job well done, in the intensity of research and in the sense of responsibility.

The construction of large generators and motors is one of the classical examples of a manufacturing process based on well-established traditions: Ever since Werner Siemens built his first dynamoelectric machine in 1866, generations of workers and technicians have worked untiringly on the exploitation of the electro-dynamic principle. To-day the Siemens-Schuckert generators supply a million times more power than the first machine in 1866.





Dynamoelectric machine built by Werner Siemens in 1866

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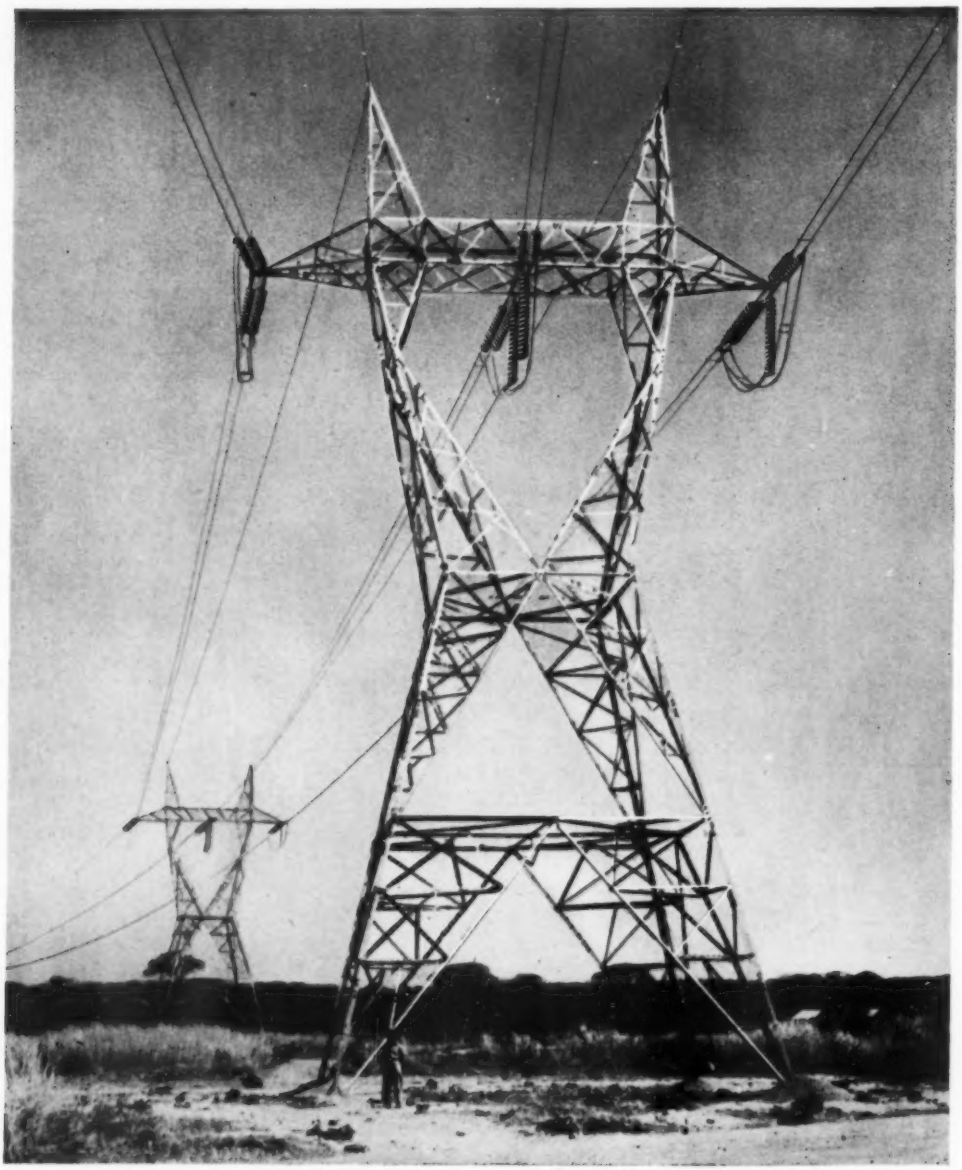
"VOLPATO"

COMPLETE EQUIPMENT FOR H.V. LINES FROM 30 KV TO 380 KV
SUB STATIONS AND POWER PLANTS . COMPRESSION MATERIAL

HIGH-GRADE SPECIALIZED MANUFACTURERS — 35 YEARS OF EXPERIENCE



TOTAL EQUIPMENT FOR THE LONGEST 220 kV OVERHEAD LINE IN AFRICA - Connecting Haut Katanga (Belgian Congo) to Northern Rhodesia - (Le Marinel - Jadotville - Kitwe) Twin Conductors - 500 km

SOC. ELETTRO-MORSETTERIE VOLPATO - VIA B. CAVALIERI. 3 - MILANO - ITALY

CATALOGUES AND PRICES ON REQUEST

TOSSING A LIFELINE

is a big job when the line is seventeen and a half miles of four-foot steel pipe. And of course the stake is correspondingly great: this line means not the rescue of one ship but water for 400,000 people.

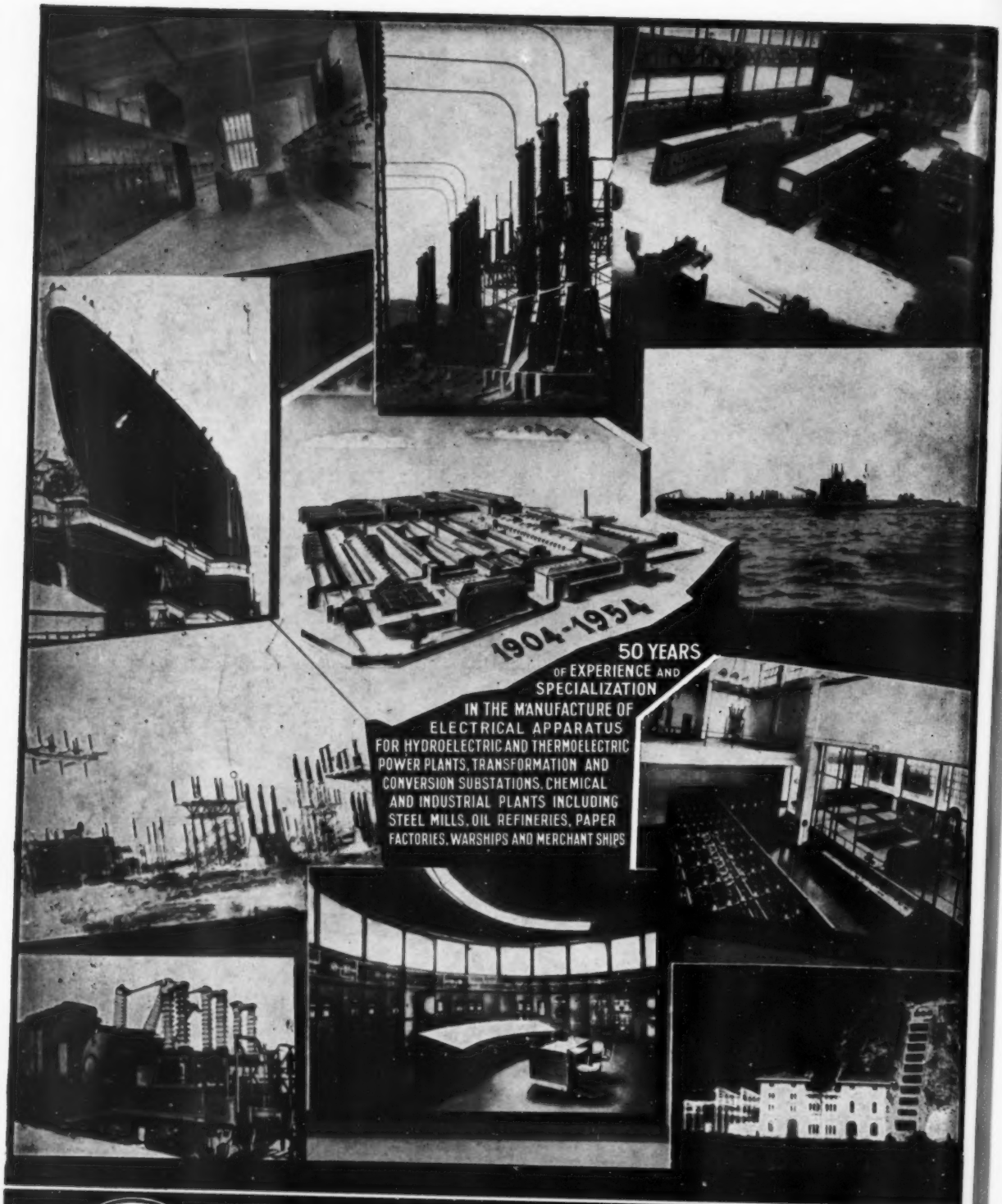
It's a big job, true enough — yet all in the day's work to Mannesmann, creators of the seamless steel tube, producers of coal, steel, welded and seamless pipe, sheet steel, and machinery, designers and builders in structural steel, and layers of pipelines.

This particular water conduit is electric welded and has walls between $^{2}/_{5}$ and $^{11}/_{16}$ inch thick, to withstand pressures of from 140 to 640 pounds per square inch. It happens to run from the Rio Tuy to Caracas, in Venezuela, but there is hardly a country that does not owe some of its water supply to Mannesmann pipe.

K/322 E

MANNESMANN-EXPORT GMBH DÜSSELDORF

REPRESENTATIVES ALL OVER THE WORLD



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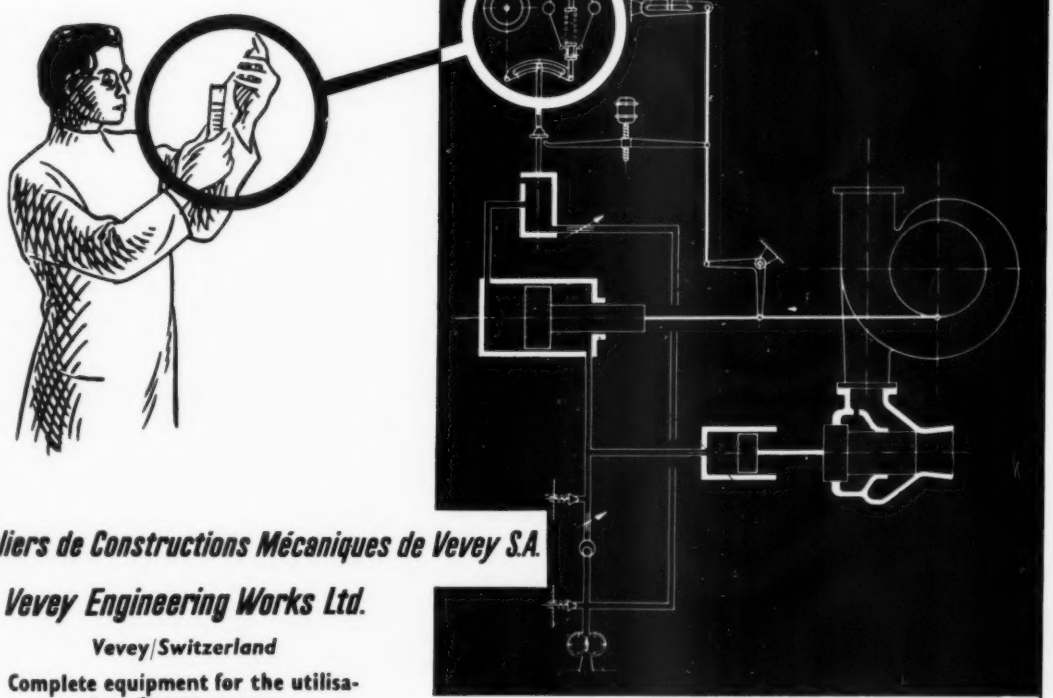
is the only one allowing exact control of the effects of the accelerometer and tachometer during operation. This particular quality makes the VEVEY governor a modern apparatus insuring great sensitiveness in speed regulation combined with improved running stability.



Ateliers de Constructions Mécaniques de Vevey S.A.

Vevey Engineering Works Ltd.

Vevey/Switzerland

Complete equipment for the utilisation of water power

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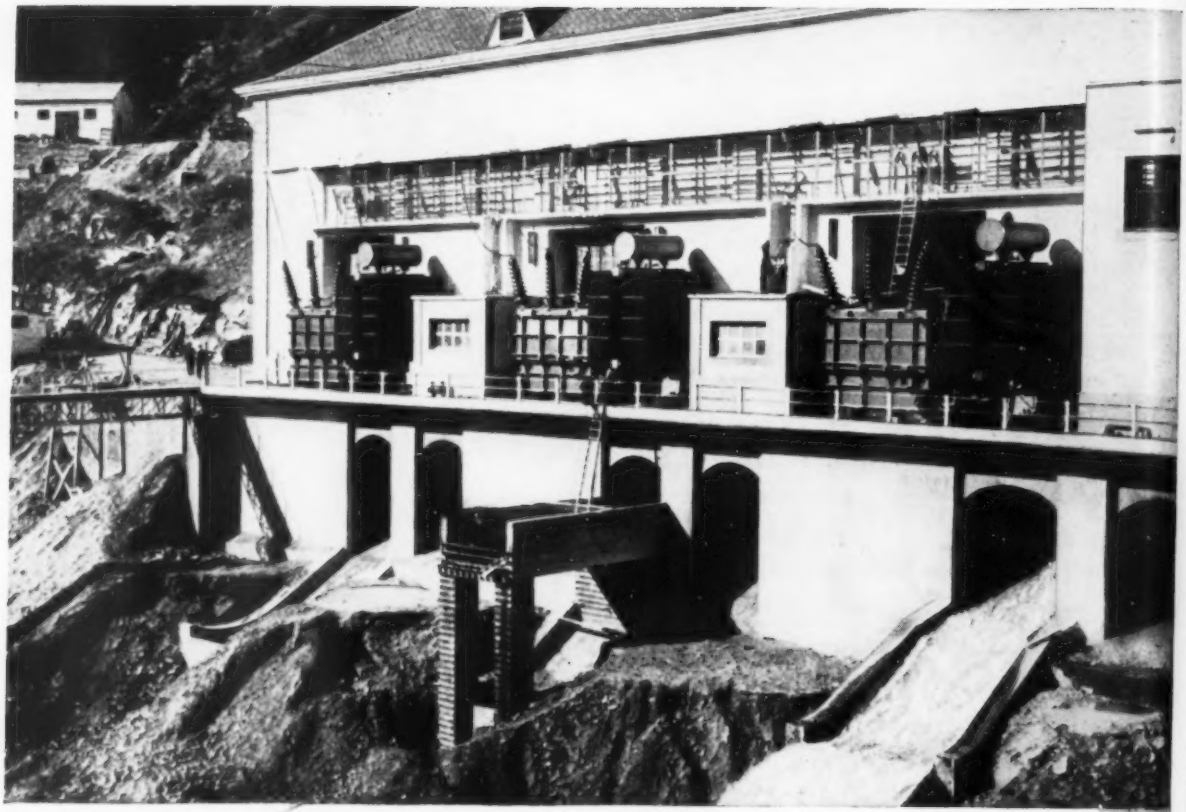
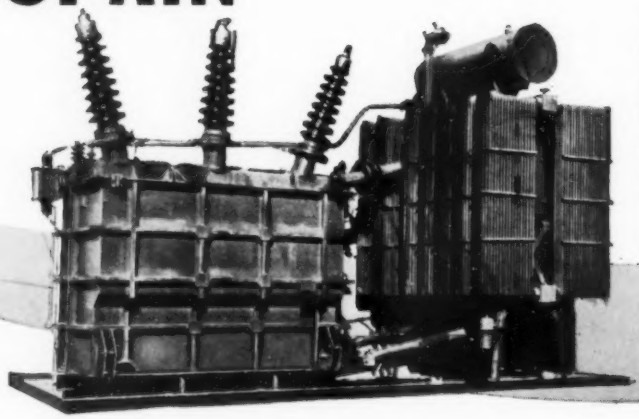


Three 16,000 kVA 6.6/138 kV Transformers at the Saltos del Sil Power Authority. The transformers were specially constructed to meet site requirements.

G.E.C.

TRANSFORMERS IN SPAIN



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On it goes . . .

and years of protection lie ahead whether it be Bridge, Barn, Dock or Derrick. If you are a maintenance man it will pay you to know more about "BITUMASTIC" coatings. A copy of our latest Brochure will be sent on request.

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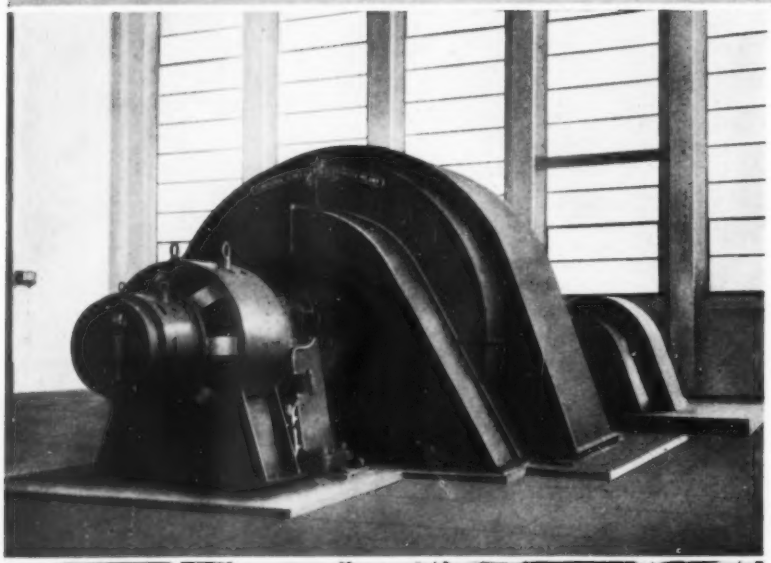
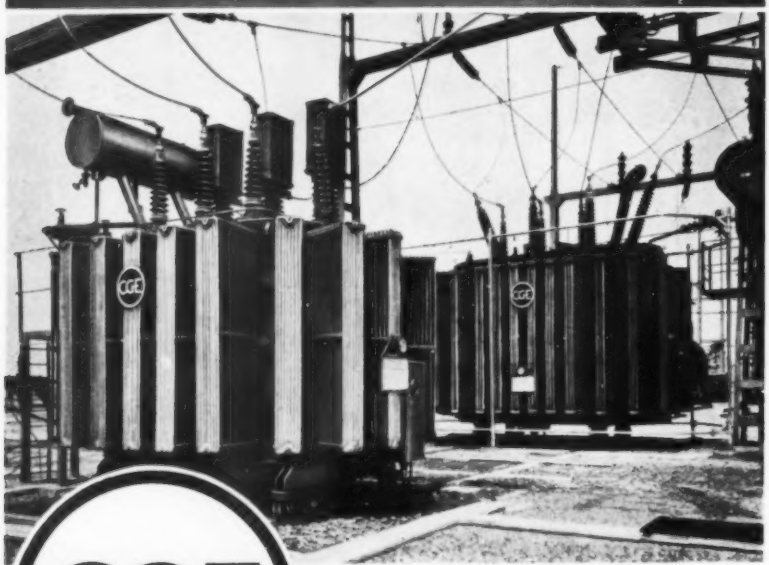
CGE
Transformers and Generators



View of
the machine hall of
Gèdre Héas Power Station
(Electricité de France)
showing the
CGE generator rated
15 000 KVA, 750 r.p.m.,
6 KV, 50 c/s.



Power transformer
30/35/20 MVA,
150/63/10 KV, fan-cooled
with regulating
autotransformer on the
63 KV side.
Five of such groups
were supplied by CGE to
the Electricité de France.

CGE

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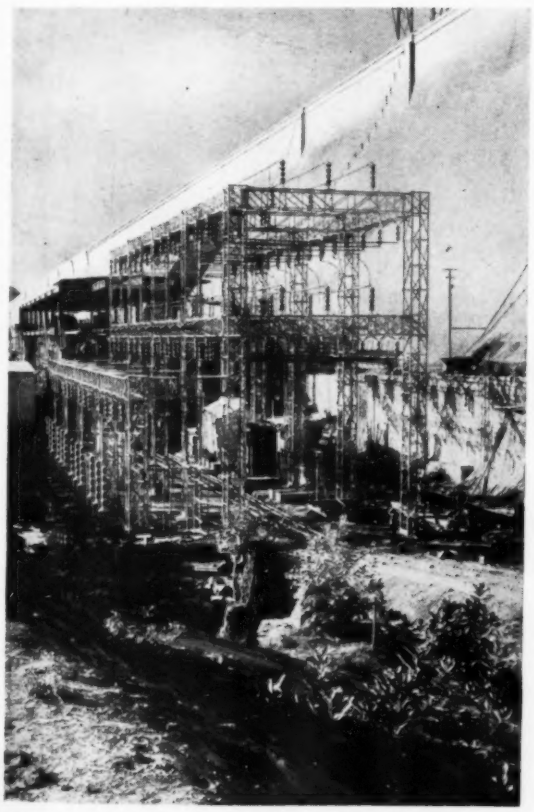
EQUIPMENT, SWITCHGEAR, RADIO, DOMESTIC APPLIANCES.

The Mettur Dam sub-station is one of many in South India equipped with posts type P.642 for 66KV and 110KV.



Photograph reproduced by courtesy of the main contractors, Messrs. A.E.I. (India) Ltd.

S.P.P. POST INSULATORS were used for the METTUR DAM SUB-STATION MADRAS

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S.P.36

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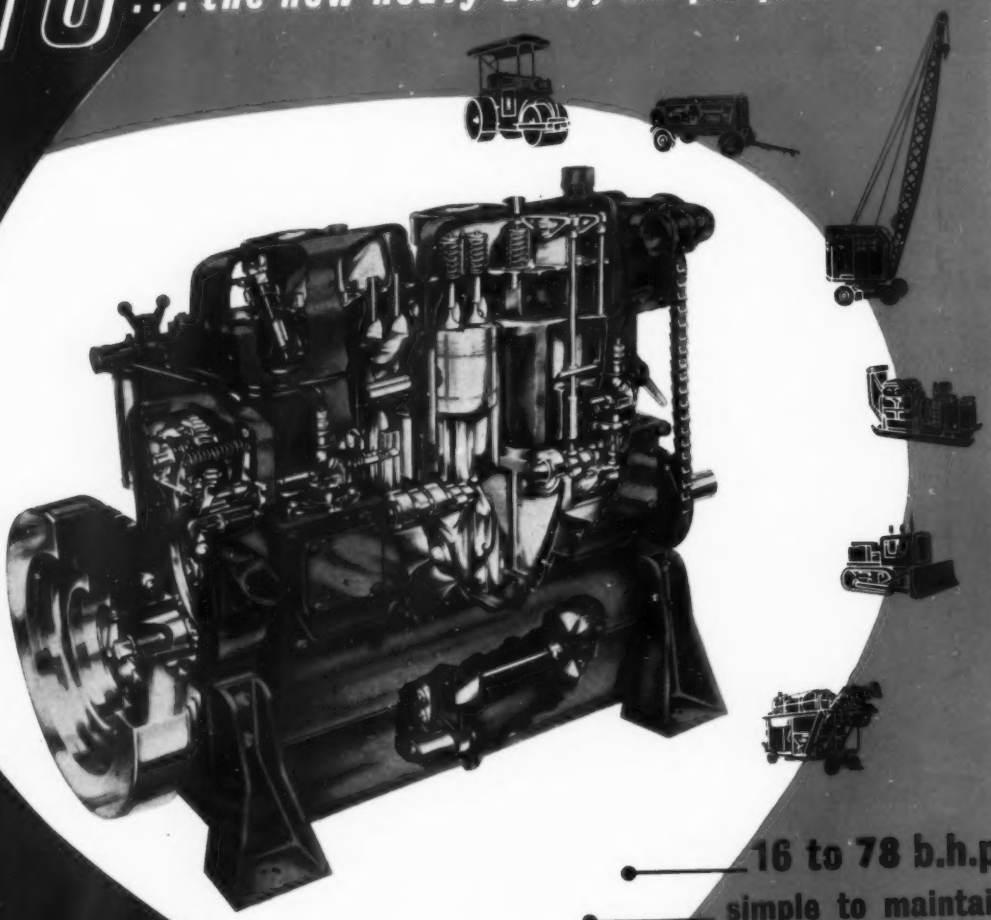

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flexible in application
compact · sturdy · reliable

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MOVABLE AND STATIONARY SCREEN CLEANING MACHINES
SURGE TANK EQUIPMENT
UPSTREAM AND DOWNSTREAM STOP LOGS
BOTTOM OUTLETS AND INTAKE GATES
ELECTRICALLY WELDED PRESSURE PIPELINES
FOR WATER POWER STATIONS

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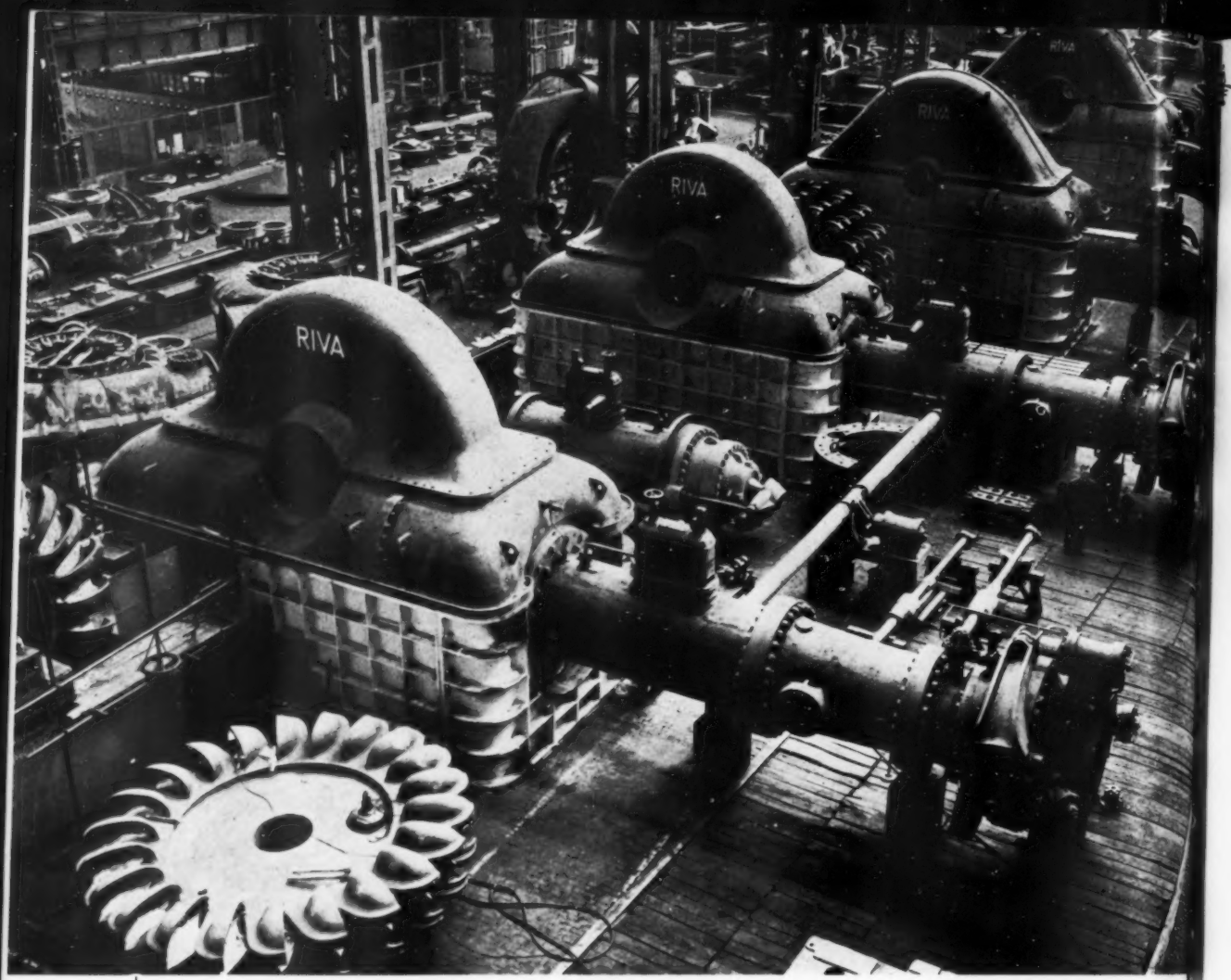


Main units actually in course of construction in our works:

PELTON : 2 Turbines each of 150,000 h.p. for Cimego Power Station, Italy.
2 Turbines each of 110,000 h.p. for Premadio Power Station, Italy.
2 Turbines each of 60,000 h.p. for Orlu Power Station, France.
3 Turbines each of 45,000 h.p. for Hospitalet Power Station, France.

FRANCIS : 2 Turbines each of 80,000 h.p. for Somplago Power Station, Italy.
1 Turbine of 24,000 h.p. for Merdj-ez-Erraguène Power Station, Algeria.

KAPLAN : 1 Turbine of 35,000 h.p. for La Penna Power Station, Italy.
3 Turbines each of 15,000 h.p. for El Oviachic and Mocuzari Power Stations, Mexico.

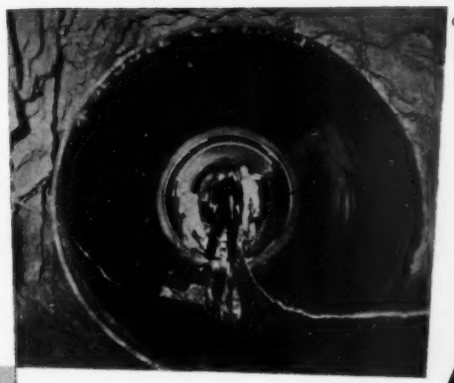
PUMPS : Two centrifugal pumps, each absorbing 27,000 h.p., for Water Storage Plant at Lettälven, Sweden.
2 centrifugal pumps, each absorbing 16,000 h.p., for Water Storage Plant at Hospitalet, France.

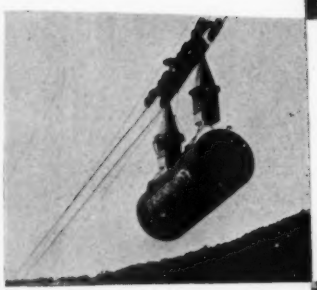
RIVA

COSTRUZIONI MECCANICHE RIVA
MILANO

VIA STENDHAL 34

CABLE ADDRESS: RIVATURB





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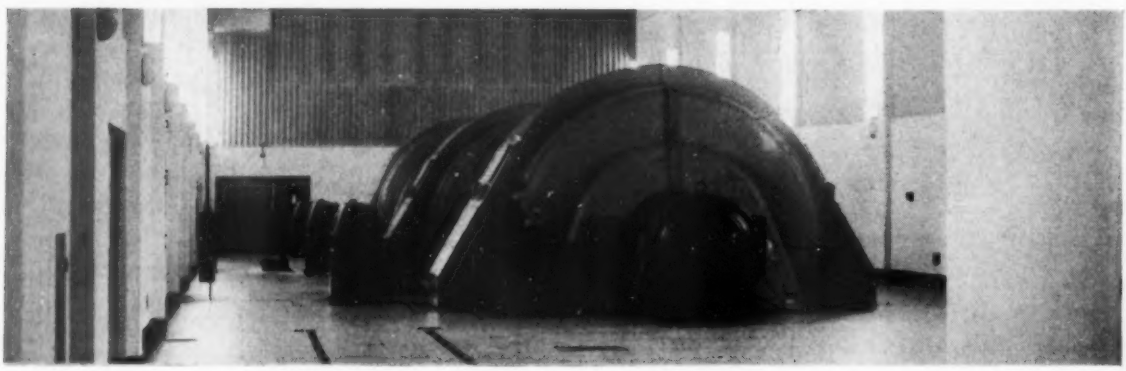


Oerlikon Generators

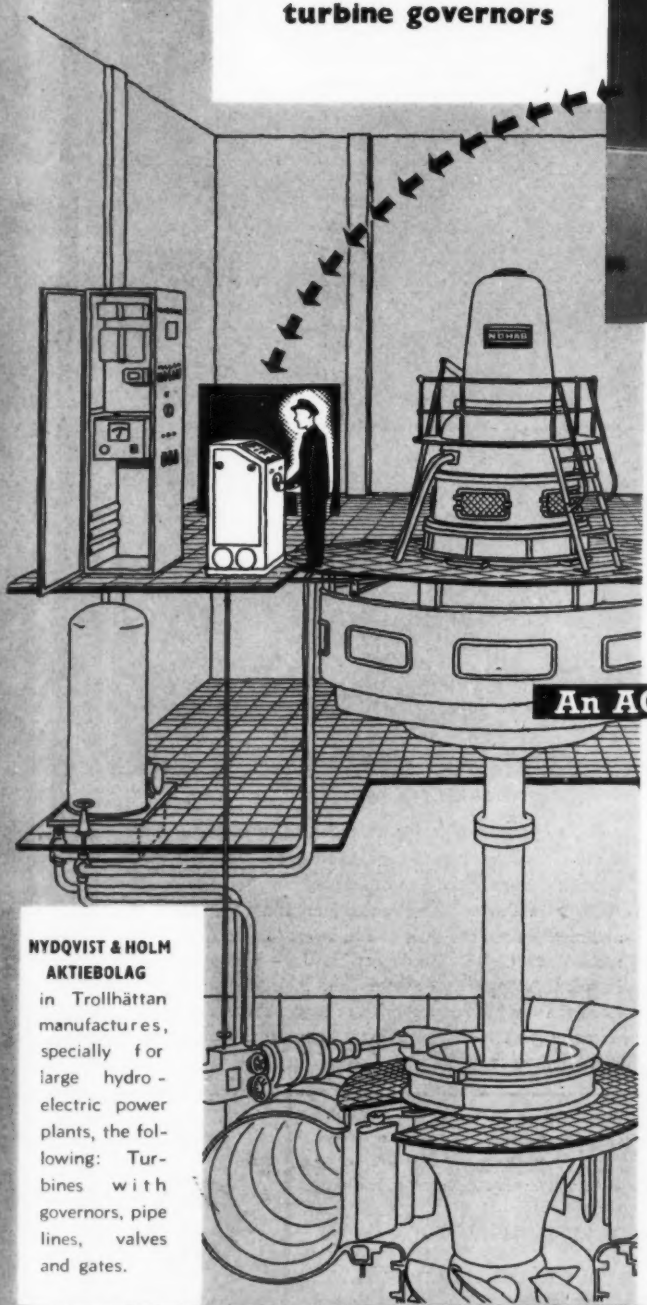
are backed by over 60 years of experience and have earned a world wide reputation as reliable elements of ever increasing power systems. The Oerlikon Engineering Company are well equipped to manufacture and erect Generators for hydro-electric power stations and complete substations in any part of the world. The photograph illustrates two 37,500 kVA, 500 r. p. m. Oerlikon Generators at the underground power station Miéville (Switzerland). We also manufacture Transformers, Switchgear, High and low voltage Apparatus, Rectifiers, Electrolysers, Electric traction equipment.

Oerlikon Engineering Company Zurich 50 (Switzerland)

Associated companies and representatives in most parts of the world.

NOHAB

electro - hydraulic turbine governors



Experience has shown that the actuators constructed by us for electro-hydraulic regulation meet the exacting demands of a good regulating and expanding control system. Our actuators solve all problems within this scope in a radical, convenient and flexible manner because all control quantities are produced electrically. The most suitable operation is guaranteed in every practical case, both statically and dynamically.

An ACTUATOR for BIG JOBS

Nohab's actuators have already been installed in many large power plants throughout Sweden, such as: Midskogsforsen, Harsprånget, Skallböle, Laforsen, Dönje, Hojum, Storfinnforsen, and several others. The number is increasing rapidly, and manufacture is geared to assembly-line production.

It is of utmost importance in the operation of a large, synchronized power network that the various stations are provided with such regulatory facilities that the most advantageous use is made of natural power. In this respect Nohab's electro-hydraulic system, which can be easily installed to meet the most varied demands, is an important step towards a more effective supply of power.

NYDQVIST & HOLM AKTIEBOLAG in Trollhättan manufactures, specially for large hydro-electric power plants, the following: Turbines with governors, pipe lines, valves and gates.

CONTACT

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NYDQVIST & HOLM AKTIEBOLAG
TROLLHÄTTAN, SWEDEN
Telegram: Nohab, Trollhätton

AWCO ACHIEVEMENTS

AWCO 37/·110" SCA Conductor, Machkund Project, Madras

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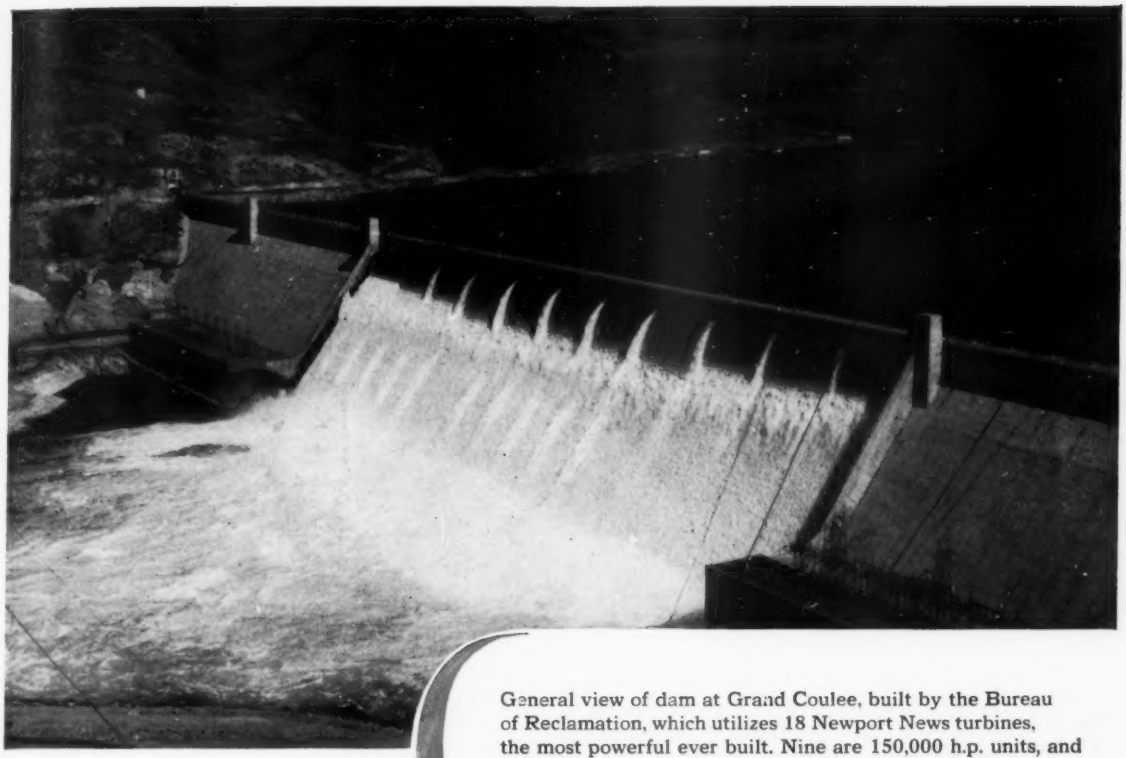
AWCO

AP210·197



General view of dam at Grand Coulee, built by the Bureau of Reclamation, which utilizes 18 Newport News turbines, the most powerful ever built. Nine are 150,000 h.p. units, and the other nine are rated at 165,000 h.p. each.

Specialists ... in building Water Power Equipment

Typical Users of Newport News Equipment

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Buchanan	Texas
Caonillas	Puerto Rico
Chief Joseph	Washington
Clark Hill	South Carolina
Deer Lake	Newfoundland
Folsom	California
Fort Patrick Henry	Tennessee
Hiwassee	Tennessee
Hoover	Nevada
J. H. Kerr	Virginia
Jim Woodruff	Florida
Lower Salmon	Idaho
Norris	Tennessee
Rock Creek	California
Santee-Cooper	South Carolina
C. J. Strike	Idaho
Whitney	Texas
Wilson	Alabama

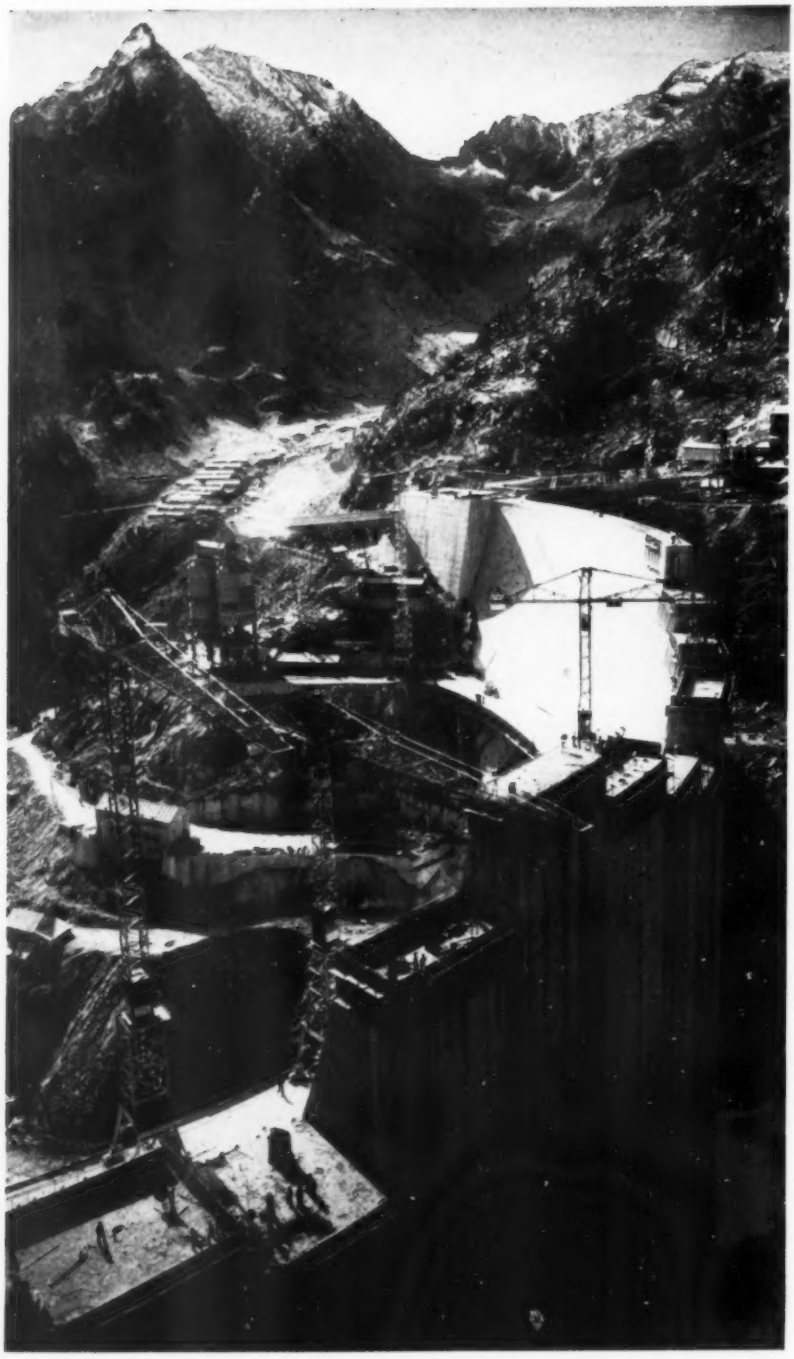
Turbines designed and built for the world's largest development at Grand Coulee... and for other hydroelectric installations in America and various parts of the world... bespeak the skill and facilities offered by Newport News.

This trained organization has filled hydroelectric turbine contracts with an aggregate rated output of 7,000,000 horsepower.

Other equipment designed and built by Newport News includes penstocks, pressure regulators, valves, pumps, gates and rack rakes. Upon request, a copy of our illustrated booklet entitled "WATER POWER EQUIPMENT" will be sent to you.

Newport News
SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia

ATLAS COPCO EQUIPMENT AT WORK ON ELEVEN FRENCH HYDRO-ELECTRIC PROJECTS



MEETING POST-WAR DEMAND

In 1949, the combined installed generating capacity of French water power stations was 5.6 million kilowatts. To meet an ever-increasing industrial and domestic demand due to post-war reconstruction, *l'Electricité de France* launched a large-scale power development programme. This included the construction of more than eleven new hydro-electric plants to harness the mountain waters of the Pyrenées, the Alps and the Massif-Central region. The installed capacity now stands at 8·5 million kilowatts. Atlas Copco equipment has been working on no less than eleven of the projects which have an installed water-power capacity totalling 1·5 million kilowatts, accounting for half the increase in capacity since 1949.

ATLAS COPCO CHOSEN AGAIN

The construction of the hydro-electric projects meant engineering on a grand scale, calling for extensive excavating and tunnelling operations. Vast quantities of Atlas Copco light rock drills and Sandvik Coromant steels were supplied by the Atlas Copco company in France, Atlas Copco France, S.A., to carry out much of this work.

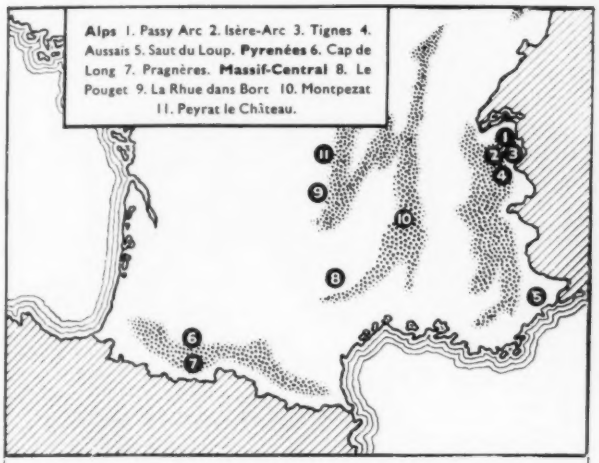
UNBEATABLE DRILLING COMBINATION

On hydro-electric projects from Brazil to Norway, Australia to Canada, Atlas Copco drills and Sandvik Coromant steels are in operation. These drills and steels were developed to work together as a lightweight drilling unit. Since its introduction, it has extensively replaced the heavy

bar-rigged drifter. Today, Atlas Copco drills and Sandvik Coromant steels are the world's most widely-used pusher leg drills and drill steels.

NEW SPEEDS AT LOWER COST

Atlas Copco light rock drills are compact, *one-man* machines. That enables you to put *more* drills into action at the face at one and the same time. More drills mean *faster* times each round and, because they are one-man machines, a reduction—in most cases—of total shift crews by at least a third. At the same time, the original capital outlay and general maintenance costs are far lower than for those of heavy equipment. So, if you want to do the job faster, and at lower cost, the Atlas Copco light rock drill is *your* machine.



Since 1949, France has built many new power stations, including eleven hydro-electric projects indicated here. Atlas Copco drills and Coromant steels have been in operation on these projects.

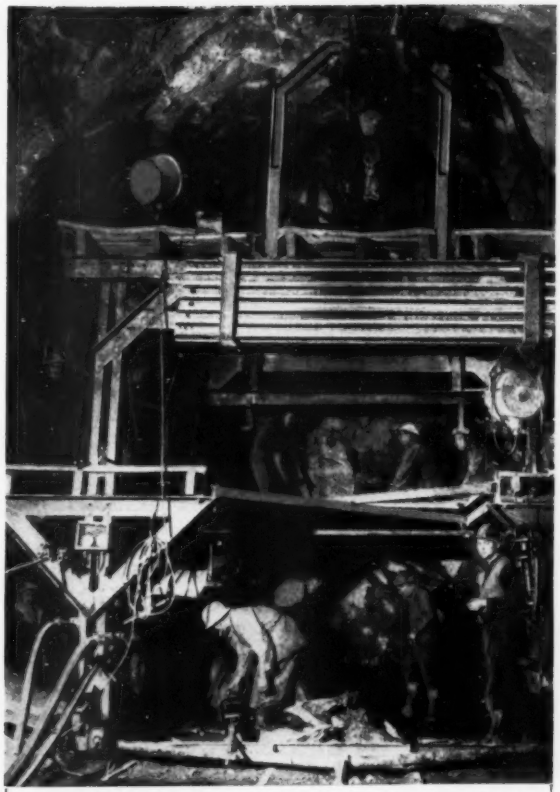
COROMANT STEELS ARE EXTRA-TOUGH

At the drilling end of Atlas Copco rock drills you'll find Sandvik Coromant steels. With their extra-tough tungsten-carbide inserts, Sandvik Coromant steels show little or no loss of speed as they advance.

Sandvik, to maintain a never-varying drill steel quality, control every phase of production—from the mining of iron ore, processing of wolfram ore, to the final tungsten-carbide inserts used throughout the world wherever Atlas Copco drills are in action.

The Atlas Copco Group puts compressed air to work for the world. It embraces thirty-one Atlas Copco companies and twenty-four agents, manufacturing or selling and servicing Atlas Copco equipment in more than 50 countries throughout the world.

Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment.



Tunnelling on the Isère-Arc project on which Atlas Copco one-man drills fitted with Sandvik Coromant tungsten-carbide tipped steels were used. The mobile drilling platform was developed by the Project Department of Atlas Copco.

For further details about Atlas Copco Drills and Sandvik Coromant Steels write to the most convenient of the addresses given here:

UNITED KINGDOM, Atlas Copco (Great Britain) Ltd., Wembley, Middx; FRANCE, Atlas Copco France S.A., 29, Rue Marbeuf, Paris 8e; HOLLAND, Atlas Copco Holland N.V., P.O. Box 6056, Rotterdam; ITALY, Atlas Copco Italia S.p.A., Viale Marche 15, Milan.

CANADA, Atlas Copco Canada Ltd., Montreal, A.M.F., P.Q.; AUSTRALIA, Atlas Copco Australia Ltd., P.O. Box 54, Auburn, N.S.W.; SOUTH AFRICA, Delfos & Atlas Copco (Pty.) Ltd., P.O. Box 504, Benoni, Transvaal; U.S.A., Atlas Copco Pacific Inc., 930 Brittan Avenue, San Carlos, California; Atlas Copco Eastern Inc., P.O. Box 2568, Paterson 2, N.J.

Readers in countries outside those listed above and who do not know the name of their local Atlas Copco company or agent, please write to Atlas Copco AB, Stockholm 1, Sweden.

The services of the Project Department of Atlas Copco whose job is to draw up drilling patterns and to advise on tunnelling and mining techniques, is at the disposal of contractors everywhere without obligation

THE ATLAS COPCO GROUP OF COMPANIES

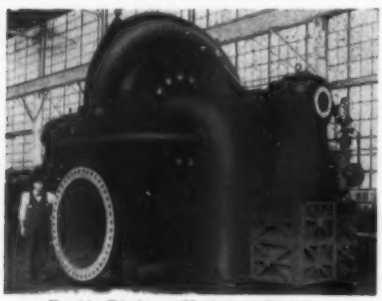
LEFFEL HYDRAULIC TURBINES

We have been continually producing hydraulic turbine equipment and accessories for the past 94 years. With this background of accumulated experience, we are prepared to give your specification or inquiries accurate and prompt attention, submitting technical and specific proposal data covering turbine equipment called for.

During this extensive period of manufacturing experience we have built hydraulic turbines which have always given the highest degree of efficiency and satisfactory performance. It is a matter of record from the beginning that Leffel turbines, as they were from time to time tested by disinterested engineers, have established progressively the highest efficiency values, ultimately reaching a maximum of **94·57% — a World's Record.**

We carry on constant technical research into refinements in the art of hydraulic turbine design, in our own testing laboratory, insuring maximum overall performance, efficiency and dependability.

Heavy, substantial construction with due regard for design and the proper use of the finest materials has always been a Company requirement.



Double Discharge Horizontal Turbine

We specialize in the design and manufacture of vertical and horizontal hydraulic turbine equipment in a wide range of capacities and types. Within this range we design and build turbines of specific speeds from the lowest practical for Francis runners to the highest practical for runners of the propeller type—all applicable according to their specific speeds to a range of heads up to approximately 1,000 feet.

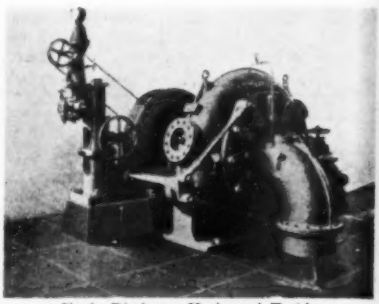
In addition to large scroll case turbines as herein illustrated we are also prepared to furnish vertical and horizontal (single or double discharge) turbines with cast or steel plate pressure cases for medium head installations as well as vertical and horizontal turbines for installation in open flumes under low heads. Such turbines may be built in capacities up to several thousand horsepower depending on conditions. They are suitable for driving generators, mill machinery and all types of miscellaneous equipment.

We also specialize in the modernization and rehabilitation of existing obsolete and inefficient hydraulic turbine equipment.

We also manufacture outdoor type electric service units completely equipped with A.C. or D.C. generators and switchboards.

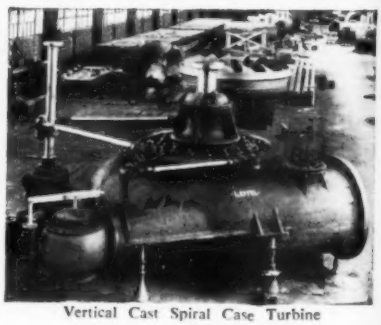
As accessory equipment we are also prepared to furnish:

Oil Pressure Governors,
Governor Accessory equipment for remote control of Automatic Plants,
Relief Valves (pressure regulators),
Gate Valves,
Steel Pipe Lines,
Head and Sluice Gate Hoists,
Trash Racks.

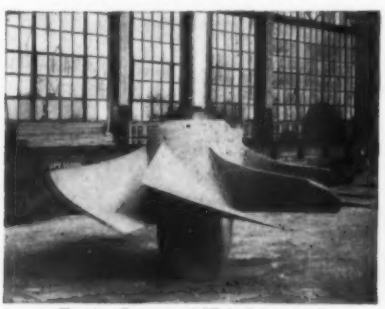


Single Discharge Horizontal Turbine

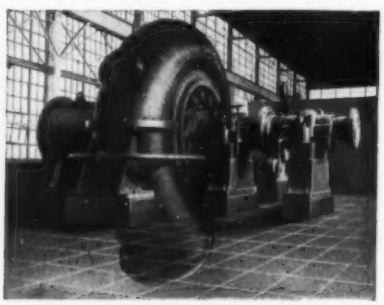
Vertical Steel Plate Case Turbine



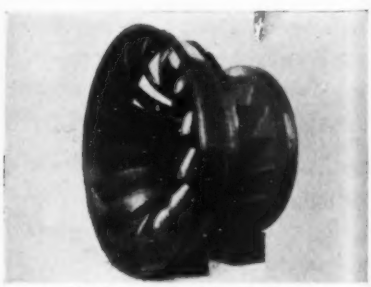
Vertical Cast Spiral Case Turbine



Turbine Runner of High Speed Type



Horizontal Steel Plate Spiral Case Turbine



Turbine runner of Francis Type

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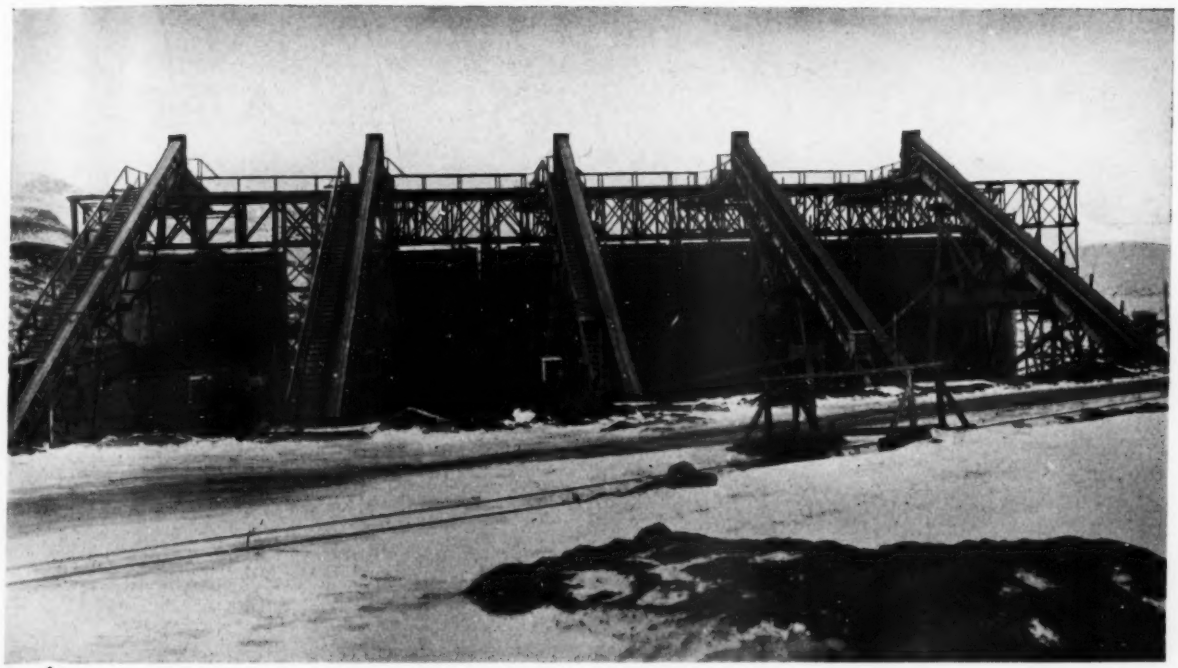

with HUWOOD conveyors.

Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes.
They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

Some hydro-electric schemes at which Huwood Conveyors have been, or are being used—

SCOTLAND.	Tummel Garry - Loch Sloy - Errochty Dam Lawers Dam
AFRICA.	Owen Falls - Uganda
INDIA.	Hirakud Dam Project

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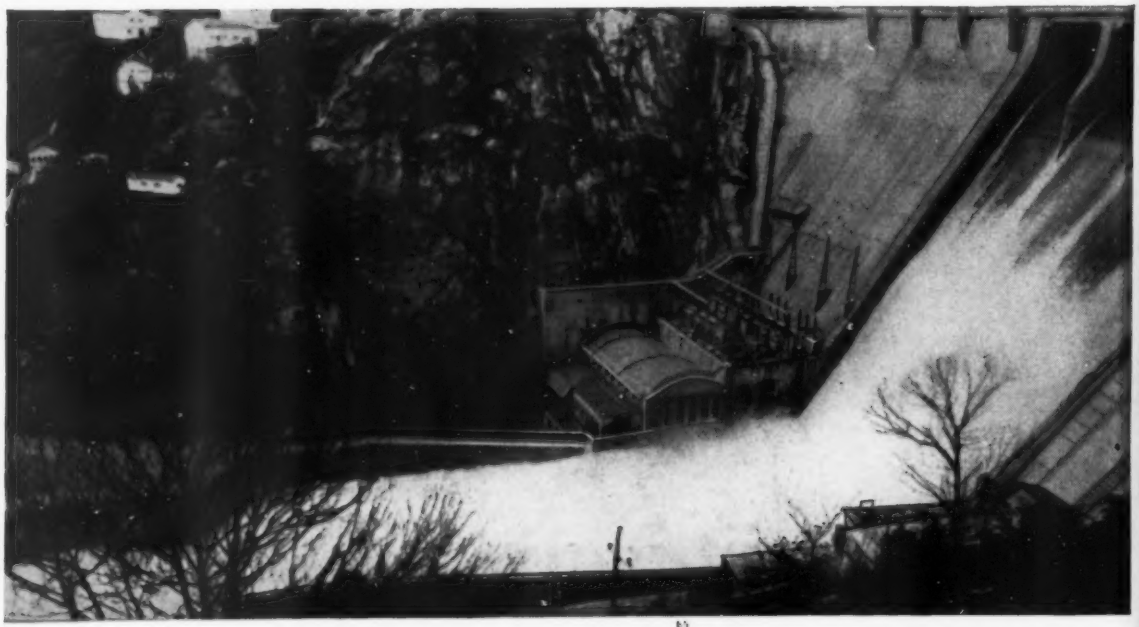
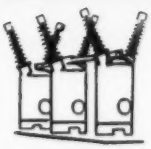
Los Peares Hydro-Electric Power Station

ANOTHER B T-H INSTALLATION



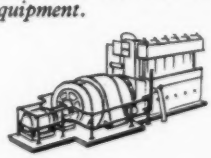
All over the world BTH hydro-electric equipment is helping to harness natural resources—helping to produce power and prosperity. In Spain, BTH (as main contractors) equipped completely the Los Peares hydro-electric power station.

Generators. Three 62,400 kVA sets with Boving Francis-type turbines.



Main and auxiliary switchgear; control and relay equipment.

Generator transformers (ten, 20,500 kVA single-phase units), and distribution transformers.



Power Station auxiliaries, including auxiliary diesel-generator.

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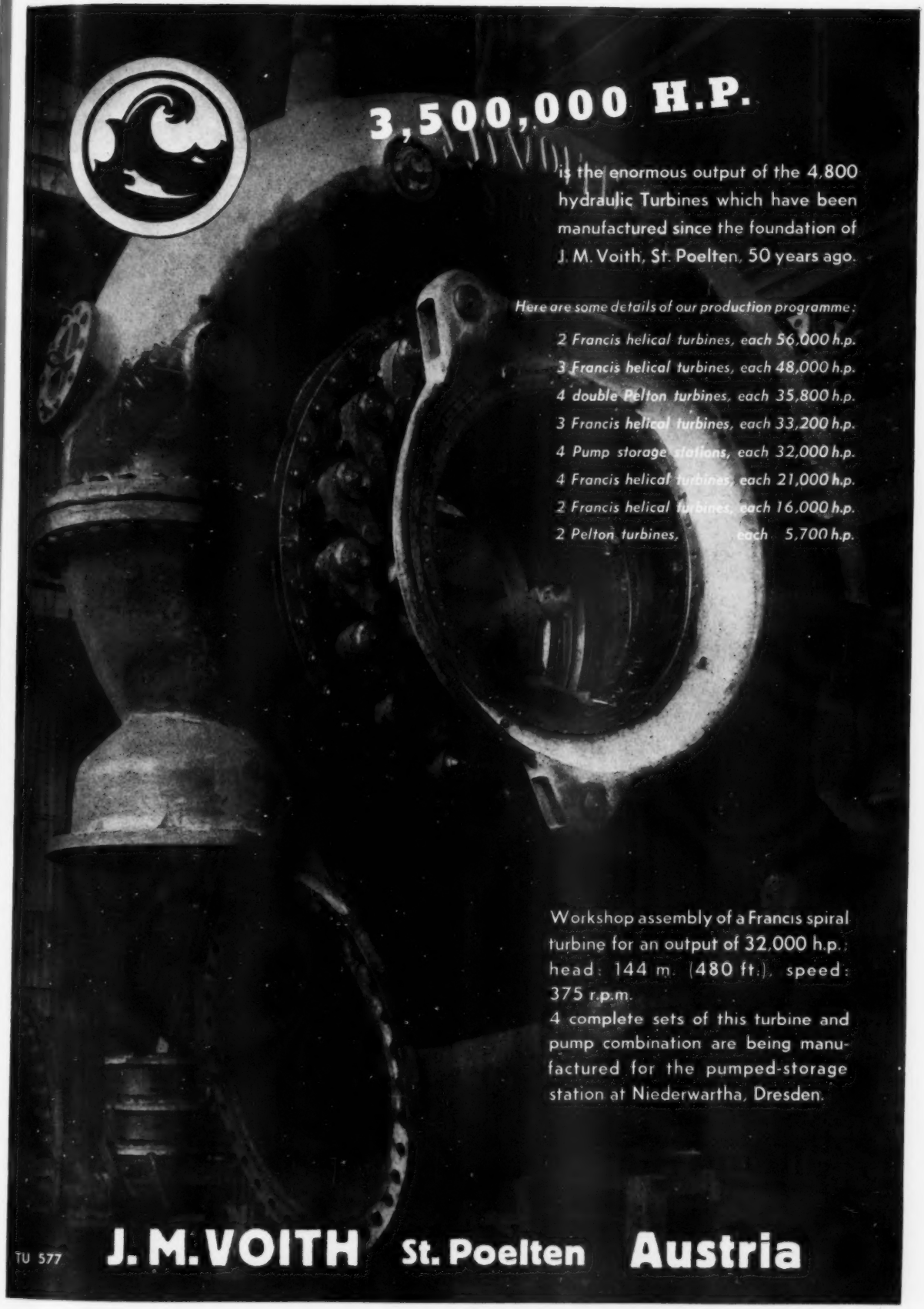
3,500,000 H.P.
is the enormous output of the 4,800 hydraulic Turbines which have been manufactured since the foundation of J. M. Voith, St. Poelten, 50 years ago.
Here are some details of our production programme:
2 Francis helical turbines, each 56,000 h.p.
3 Francis helical turbines, each 48,000 h.p.
4 double Pelton turbines, each 35,800 h.p.
3 Francis helical turbines, each 33,200 h.p.
4 Pump storage stations, each 32,000 h.p.
4 Francis helical turbines, each 21,000 h.p.
2 Francis helical turbines, each 16,000 h.p.
2 Pelton turbines, each 5,700 h.p.
Workshop assembly of a Francis spiral turbine for an output of 32,000 h.p.; head: 144 m. (480 ft.), speed: 375 r.p.m.
4 complete sets of this turbine and pump combination are being manufactured for the pumped-storage station at Niederwartha, Dresden.
TU 577
J. M. VOITH St. Poelten Austria

719,000 kVA of FERRANTI Transformers for the Alcan Project

NEW CONTRACT

Ferranti Ltd have been awarded a further order by the Aluminum Company of Canada Ltd., for 3-71,000 kVA, single phase Generator Transformers stepping up to 301,400 volts

These units will form the second 213,000 kVA bank of generator transformers to be supplied by Ferranti Ltd., for installation in the now famous "Power Station inside a mountain" of the Alcan Project at Kemano, British Columbia. The transformers will have aluminium windings, and it is believed that they will form the largest bank of transformers with aluminium windings in the world. This order brings the total number of transformers supplied or under construction by Ferranti Ltd. for the Alcan Project to 13 units of a total capacity of 719,000 kVA, to the value of 1,210,000 dollars.

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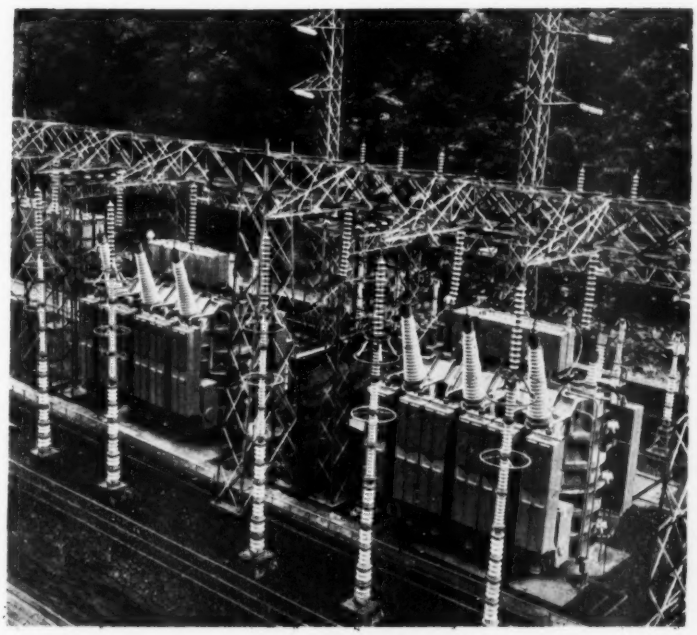
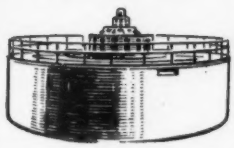
LEADS THE FIELD

Throughout the years, Hitachi, Ltd. has led the field of Japanese heavy industries in production

Especially in the development of hydraulic power resources, Hitachi, Ltd., eminently qualified for the production of water-wheel generators well over hundred thousand kw in capacity and the innumerable relevant equipment and apparatus, is continuing its contribution in Asia or any other countries wherever its industrial ability is given the opportunity of proving its true worth.



135,000 KVA Extra-High-Tension Power Transformers installed at the Kamishiba P. S. These Transformers have established a new capacity record in Asia.



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this is . . .

a cabin of one of Austria's most beautifully situated aerial cable-ways on the Penken in famous Zillertal, Tyrol.

Photo : Hans Hruschka

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the heaviest transformer ever shipped from Austria to the U.S.A., a three-phase two-winding power transformer, ratio 115/69 kV, output 83.333 kVA, for Sub-Station Umatilla, Oregon.

Photo : ELIN

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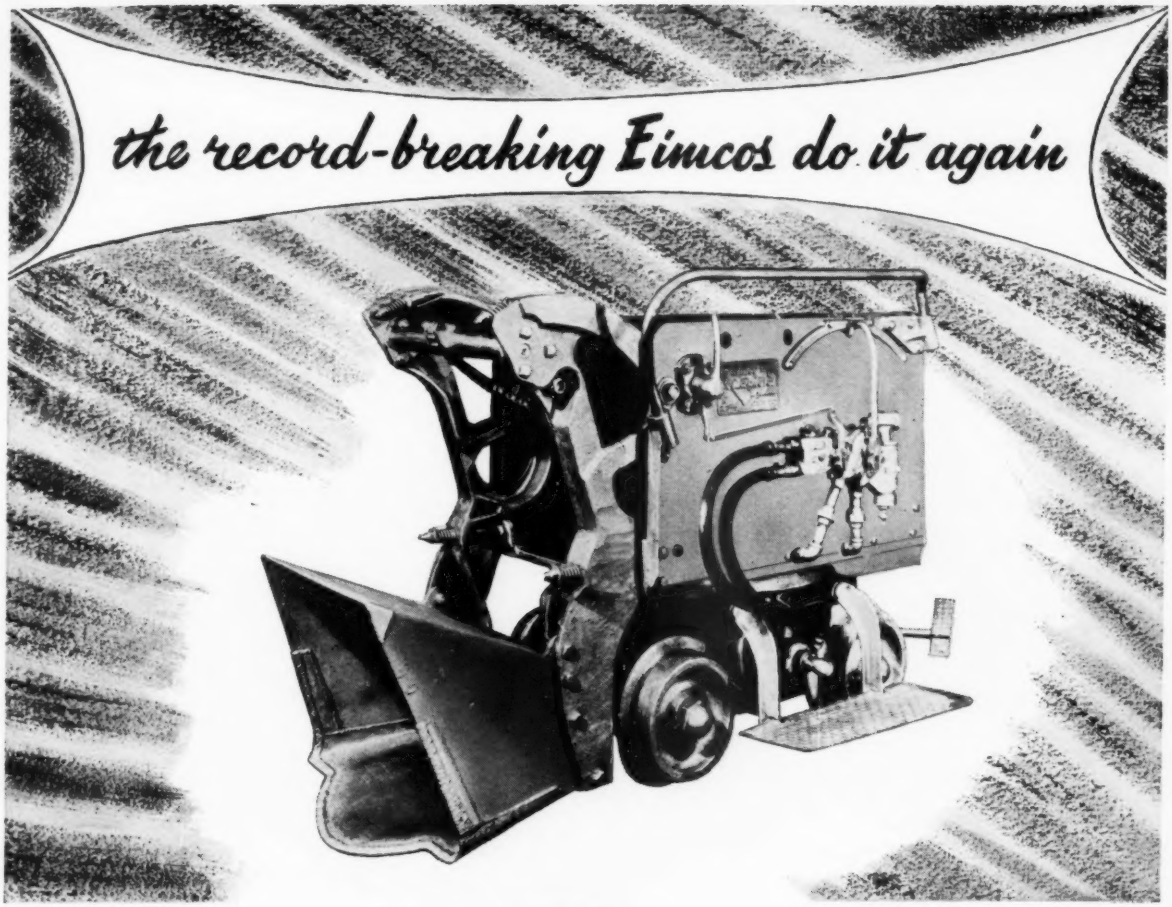
the record-breaking Eimcos do it again



A NEW WORLD TUNNELLING RECORD

has been established using **EIMCO** *MODEL 21 LOADERS*

On the St. Fillans Section of the North of Scotland Hydro-Electric Board Breadalbane project, the Mitchell Construction Company have established a new world record for rock tunnelling with an advance of 557 feet in 7 days.

The incomparable Eimco Rockershovels have made an outstanding contribution to this achievement.

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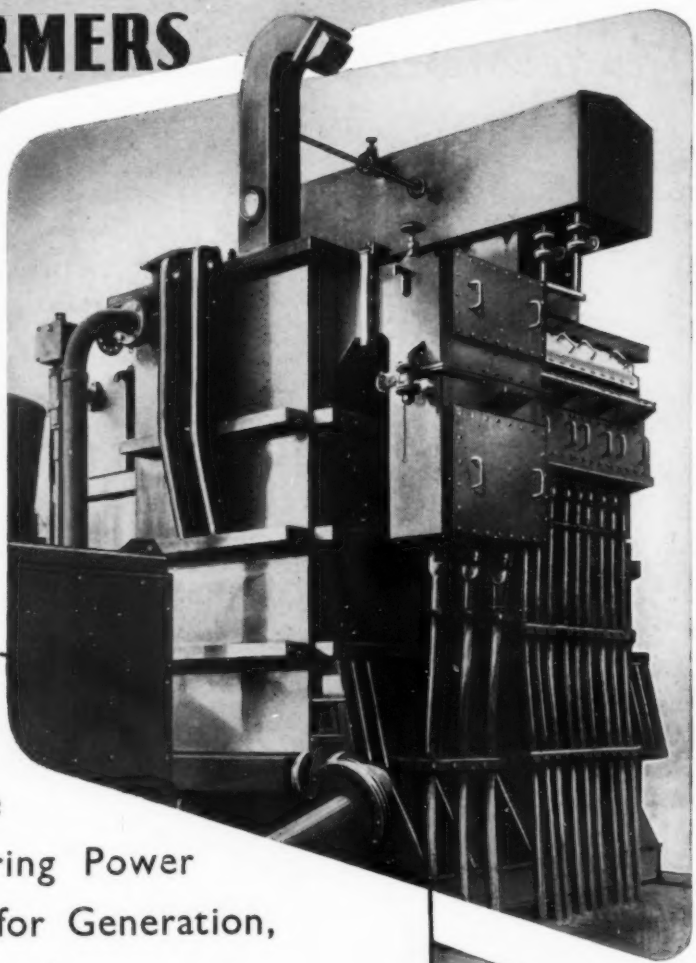

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All YORKSHIRE Transformers are entirely constructed in our own works. We make Transformers to suit all requirements up to **60,000 kVA—132,000 Volts.**

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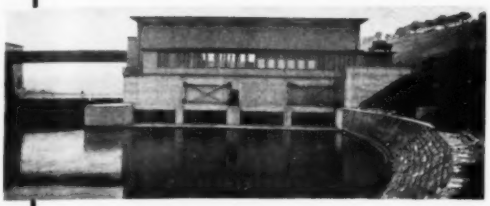

22 POWER STATIONS ON THE RIVER MAIN

8 POWER STATIONS ON THE RIVER INN

5 POWER STATIONS ON THE DANUBE

10 POWER STATIONS ON THE RIVER ISAR

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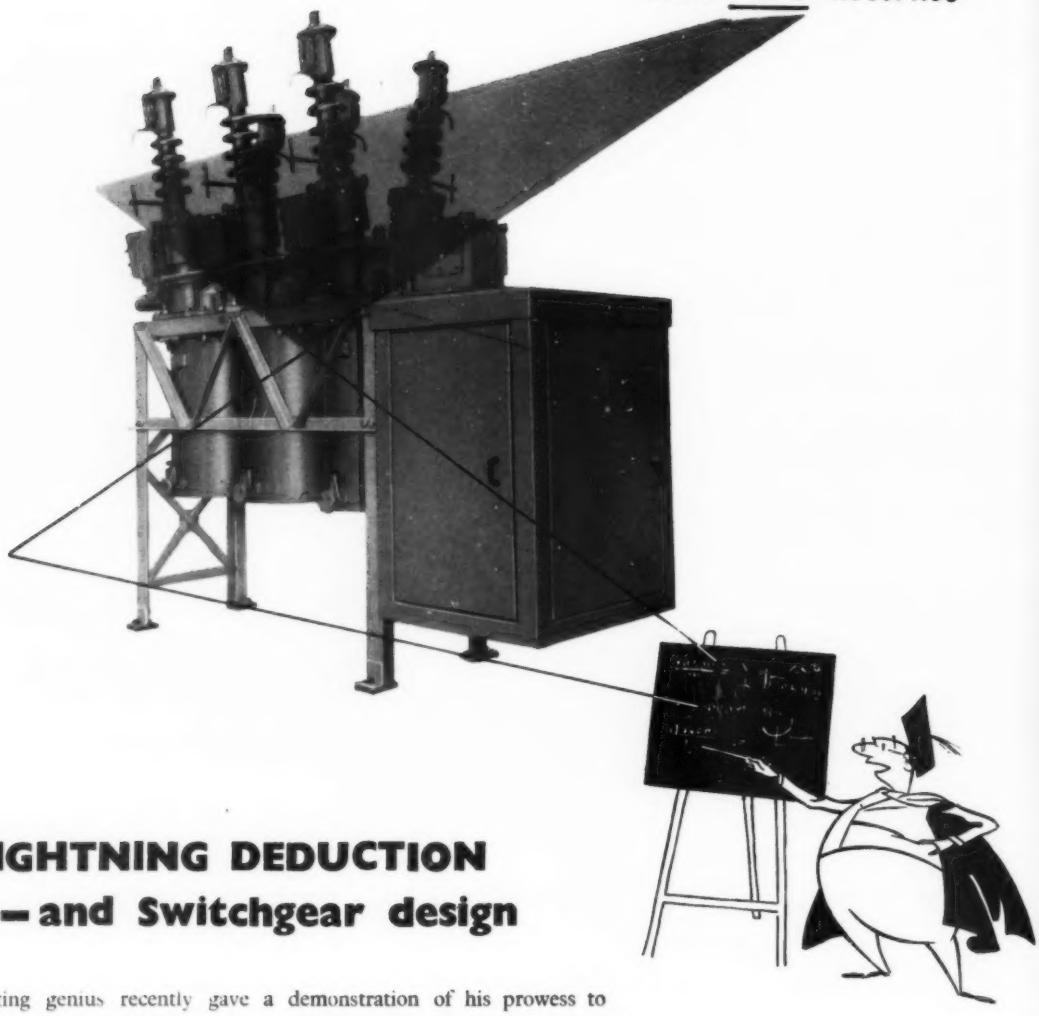
3 POWER STATIONS ON THE RIVER ENNS

AND MANY OTHERS BOTH IN GERMANY AND ABROAD

Whenever you are considering new water power developments, we shall be glad to help with your hydraulic problems

J. M. VOITH G.M.B.H., HEIDENHEIM/BRENZ, GERMANY

Not TOO abstruse



LIGHTNING DEDUCTION
– and Switchgear design

A calculating genius recently gave a demonstration of his prowess to students in the City of Manchester. Whilst the exhibition of such mental agility may be of academic interest, it is a fact that most things of practical application have been the result of lengthy thought process and experiment in the design stages as, for example, the Type TTPO.24 oil circuit-breaker of 'Ferguson Pailin' manufacture. This triple-tank breaker is a frame-mounted unit designed for 33 kV outdoor service, complying with the latest British Standards. Breaking capacities up to 1500 MVA at 33 kV have been certified by the Association of Short-circuit Testing Authorities. Special attention has been given to the protection of vital parts against the vagaries of weather and climatic conditions.

Ferguson Pailin LIMITED *for Switchgear*

Member of the A.E.I. Group of Companies

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20 ton 'TRAVELIFT' Cableway handling 8 cu. yd. capacity bottom discharge concreting bucket.

BRECO Ropeways and Cableways have been supplied and installed for operation under most extreme climatic and topographical conditions throughout the world.

BRECO — Sole manufacturers of 'Travelift' Cableways, outside the North American Continent. TRAVELIFTS are especially suited to high speed heavy construction work.

Literature available on request.

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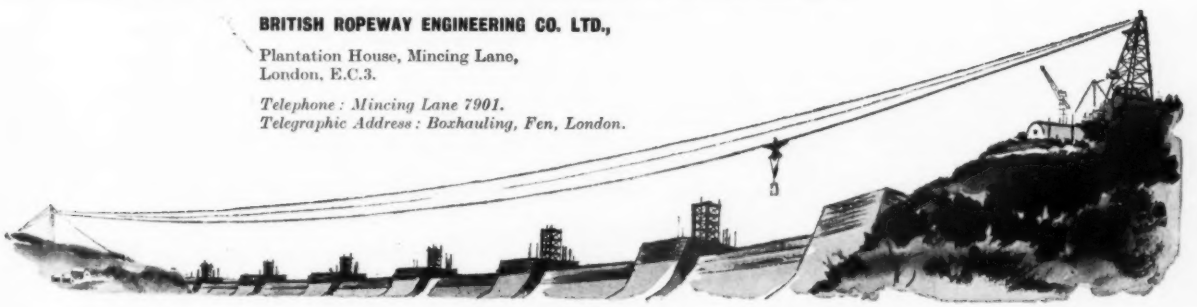
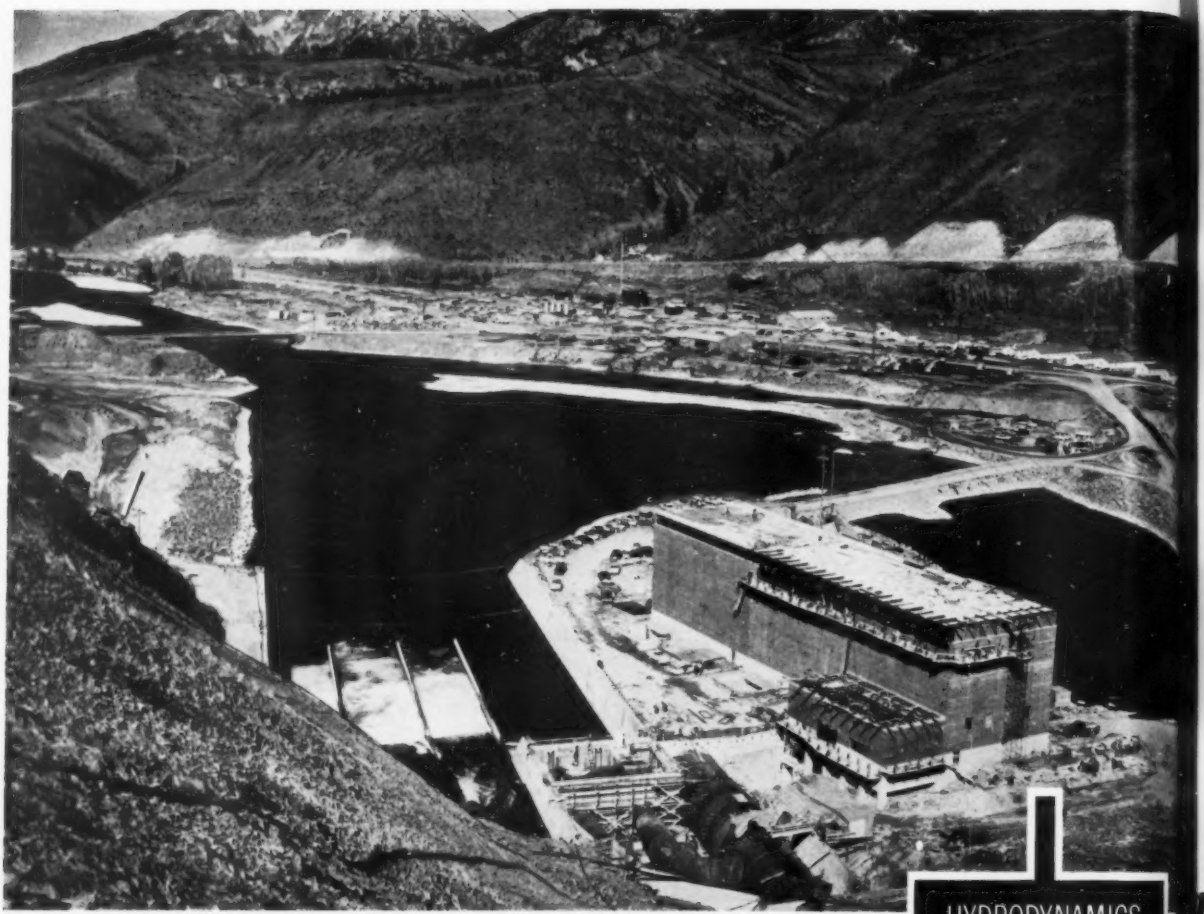
Plantation House, Mincing Lane,
London, E.C.3.

Telephone : Mincing Lane 7901.
Telegraphic Address : Boxhauling, Fen, London.





View downstream from the dam toward the powerhouse shows the irrigation bypass (left), penstock (center) and tail-race canal (right). *(U.S.B.R. photo)*

HYDRODYNAMICS

Mile-High SMS-Francis Turbines soon to deliver power at Palisades

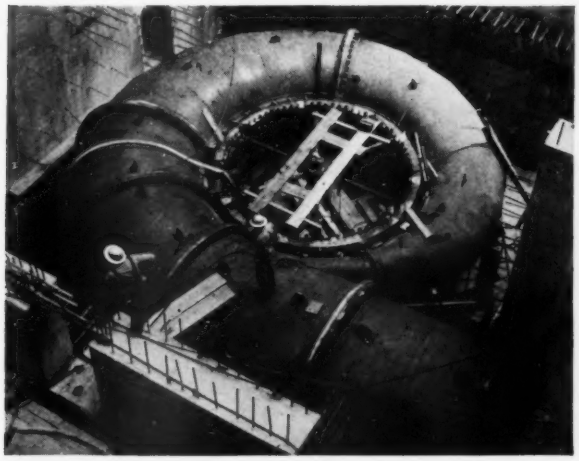
High on the south fork of Idaho's Snake River, the first of four SMS-Francis turbines at Palisades Dam is scheduled to go on the line in 1956. The Palisades Dam, which is the Bureau of Reclamation's largest earth-filled dam, is primarily an irrigation project. The dam will have a crest length of 2,100 feet, rise 270 feet above the streambed, and provide a storage reservoir some 20 miles long and 3 miles wide.

Four vertical SMS-Francis turbines will be installed to produce a total capacity of 114,000 kw. Designed to operate at a site more than a mile above sea level, each unit is rated at 39,500 HP under a 190-foot head. The power generated will serve southeastern Idaho, where Atomic Energy Commission facilities and a growing phosphate industry now tax the existing electric supply.

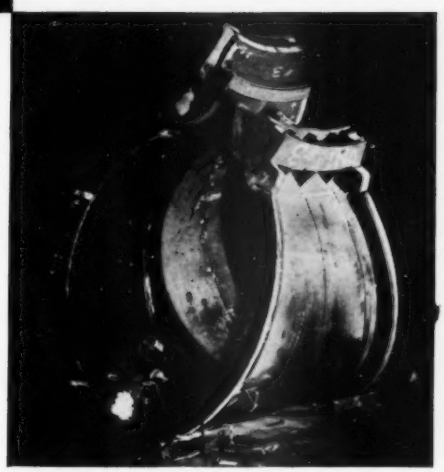
Whatever your needs in hydraulic turbines and accessories may be, S. Morgan Smith offers 79 years' background in designing and manufacturing equipment for world-wide installation. This experience – over 16,000,000 HP installed capacity – is your greatest assurance of satisfactory equipment performance. For full information, write S. Morgan Smith Company, York, Penna., U.S.A.

Inside view of the powerhouse, with the pit for Unit #1 in the foreground, and Units #2, 3 and 4 in various stages of construction to the rear. *(U.S.B.R. photo)*

Scroll cases for the Palisades turbines are shop-welded steel plate construction. *(U.S.B.R. photo)*



Final check assembly of Unit #2 – a complete scroll case, pit liner, distributor gates and operating mechanism – is made in SMS shops prior to shipment to the site.



Welding a flange to a section of Unit #3's spiral steel case. SMS shops are completely equipped to fabricate weldments of the largest types.

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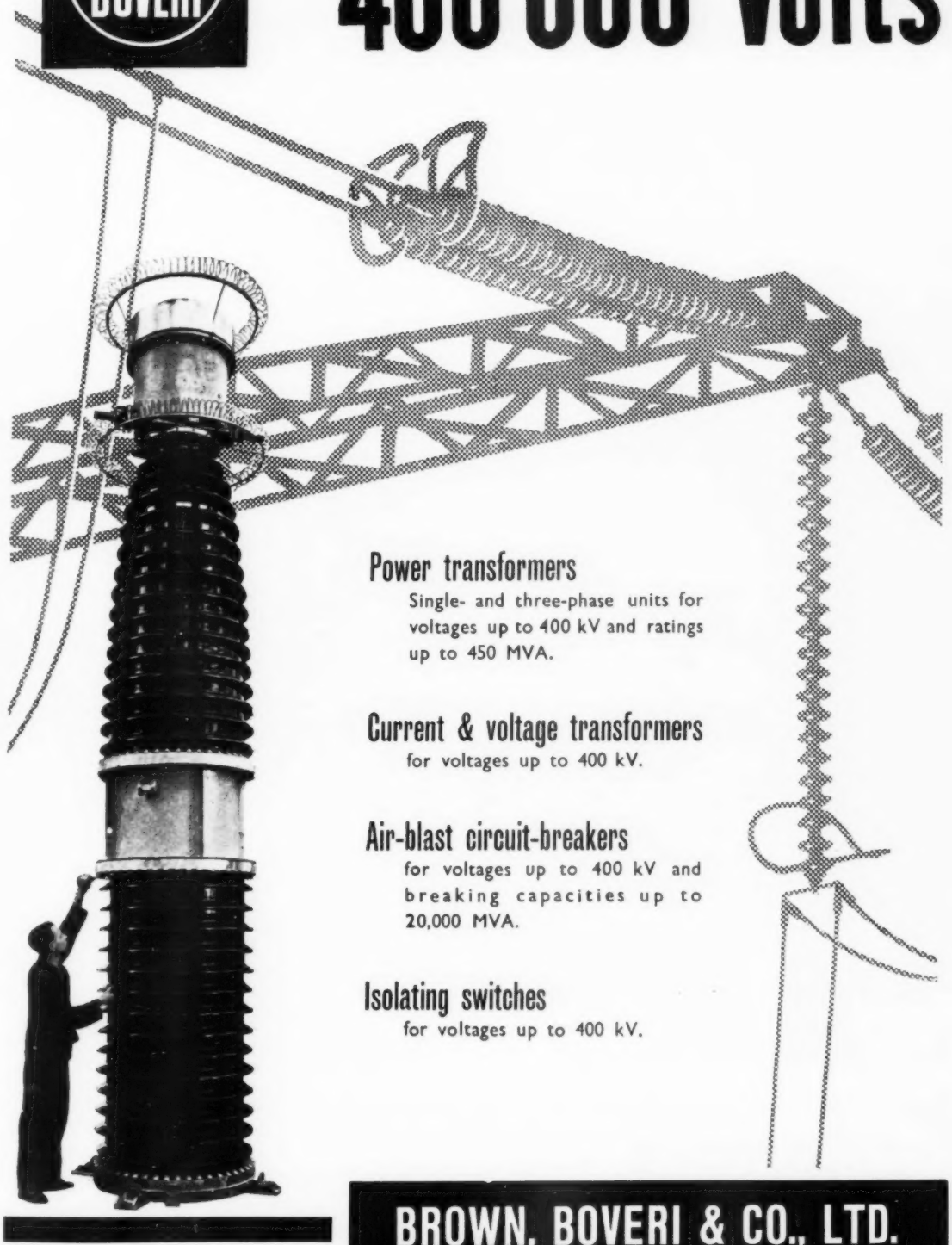

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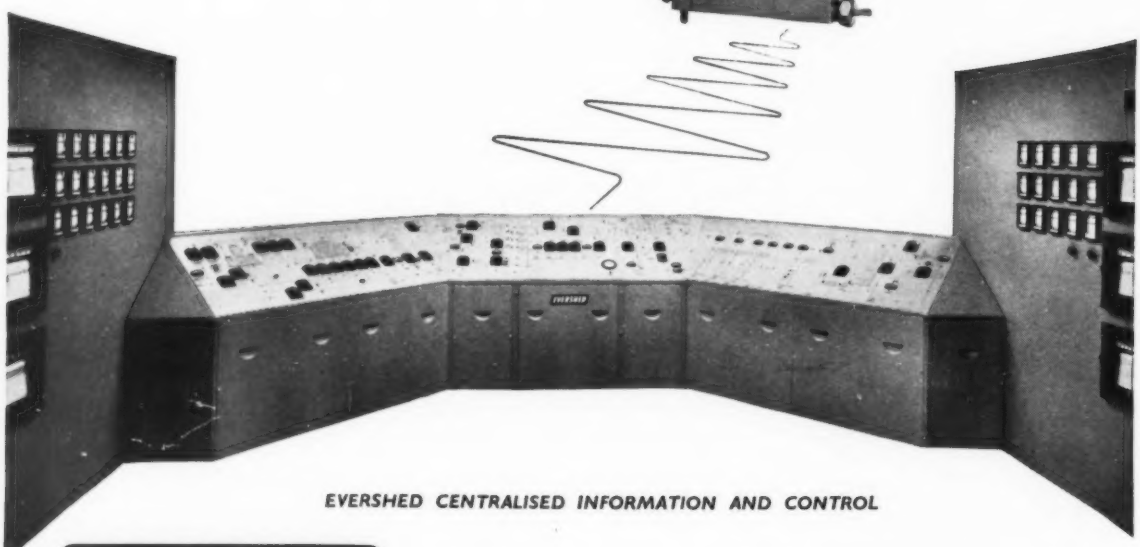

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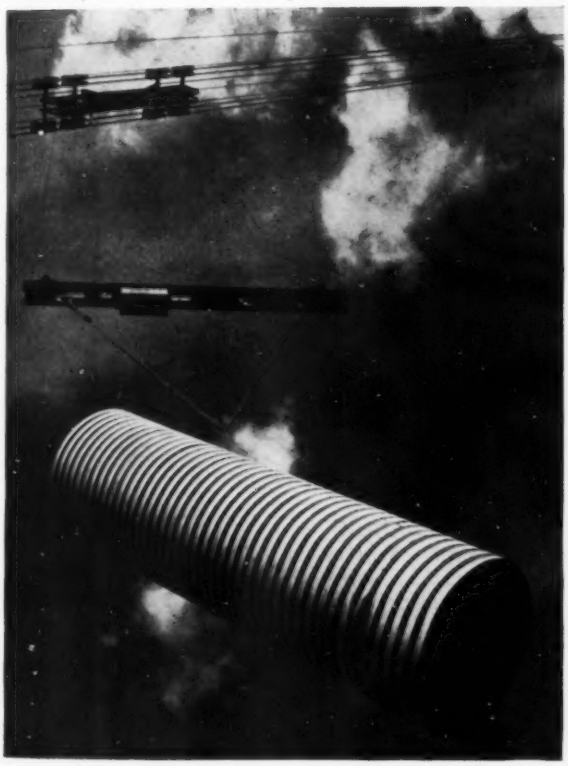

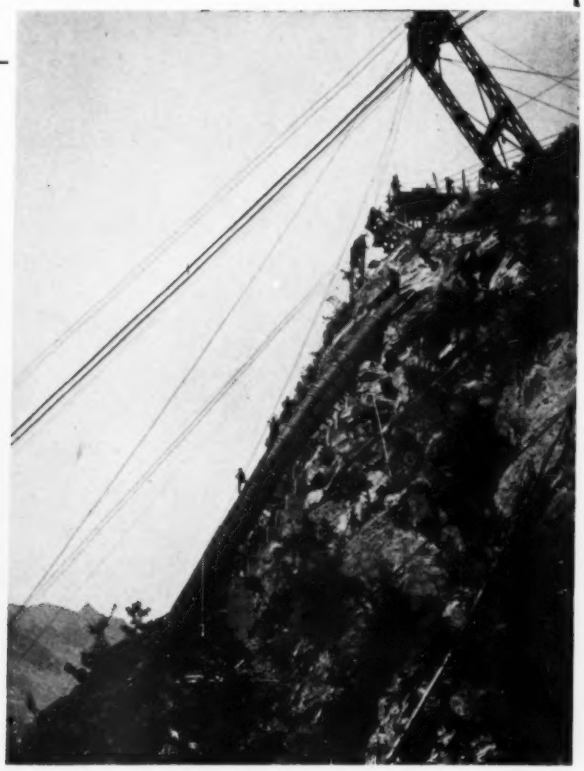

Above: Pragneres: Head 1,252m.
Flow 14·6m 3/sec. Diam. 2·25 to 1·6m.
Power 200,000 h.p.

Left: Pragneres: Self-hooped Penstock
Teleferic max. load 15 Tons
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Northern outfall works at Beckton

View of Supply Channels from Screen House with Primary Sedimentation Tanks in background.

This contract, recently completed for the London County Council, comprised the construction of Penstock Chamber, Main Supply Channel, Screen House, Supply Channels, Distribution Channels, sixteen Sedimentation Tanks, Sludge Pumping Station, Effluent Culverts and outfall works.
The works, which are designed to deal with an anticipated flow of sewage of 200,000,000 gallons a day, were constructed almost entirely in reinforced concrete.
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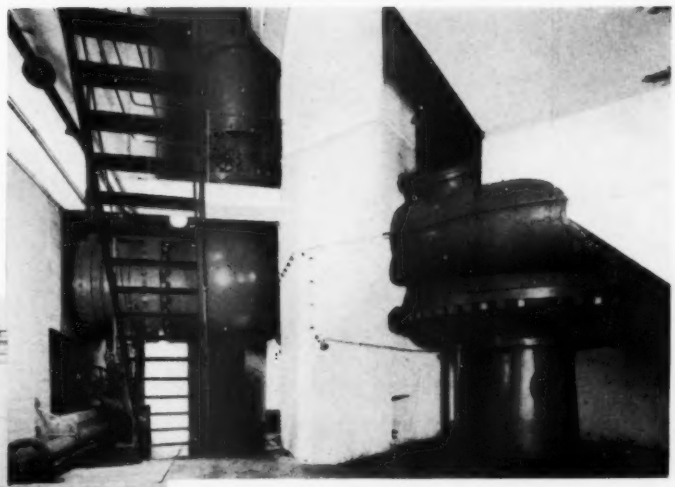
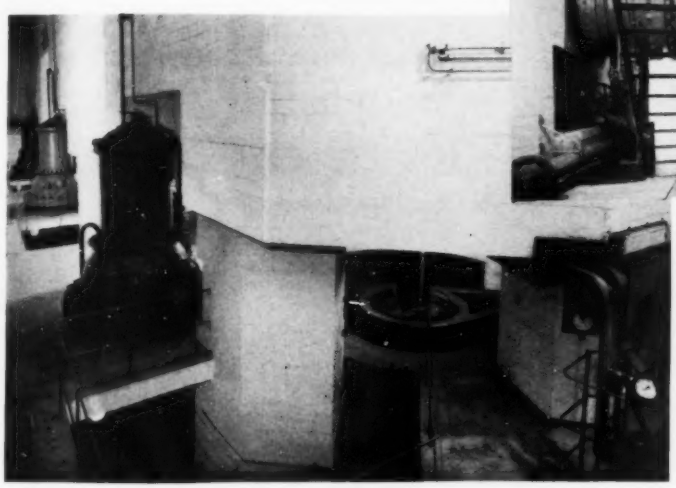


View of one of the VINSTRA turbines and main sluice va've



Governor platform showing regulator ring of one of the turbines and parts of the main sluice valves.

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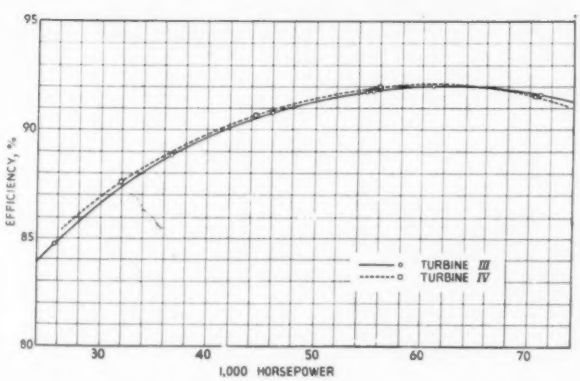

Efficiencies actually obtained on Vinstra turbines III and IV on official test, June 23-24, 1953

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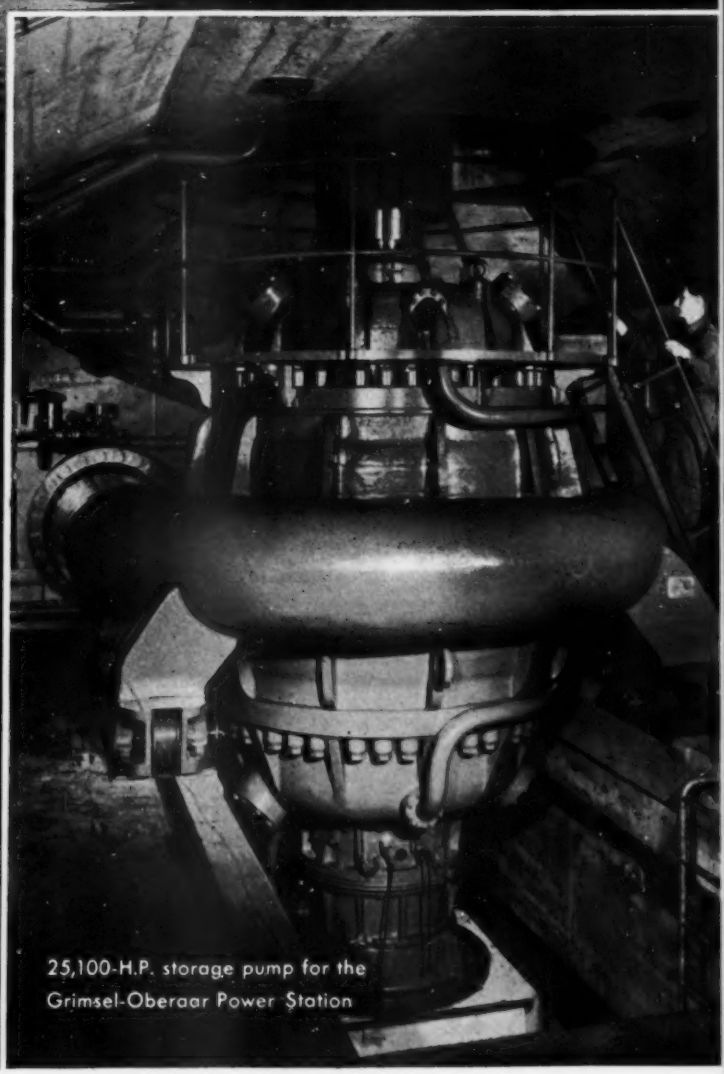
one pump for

Motec Power Station, Switzerland

(discharge 43,050 g. p. m., head 2,060 ft., speed 750 r. p. m., input 30,400 H. P.)

Lake Oberaar, 7,550 ft. above sea level, in the Bernese Oberland, Switzerland



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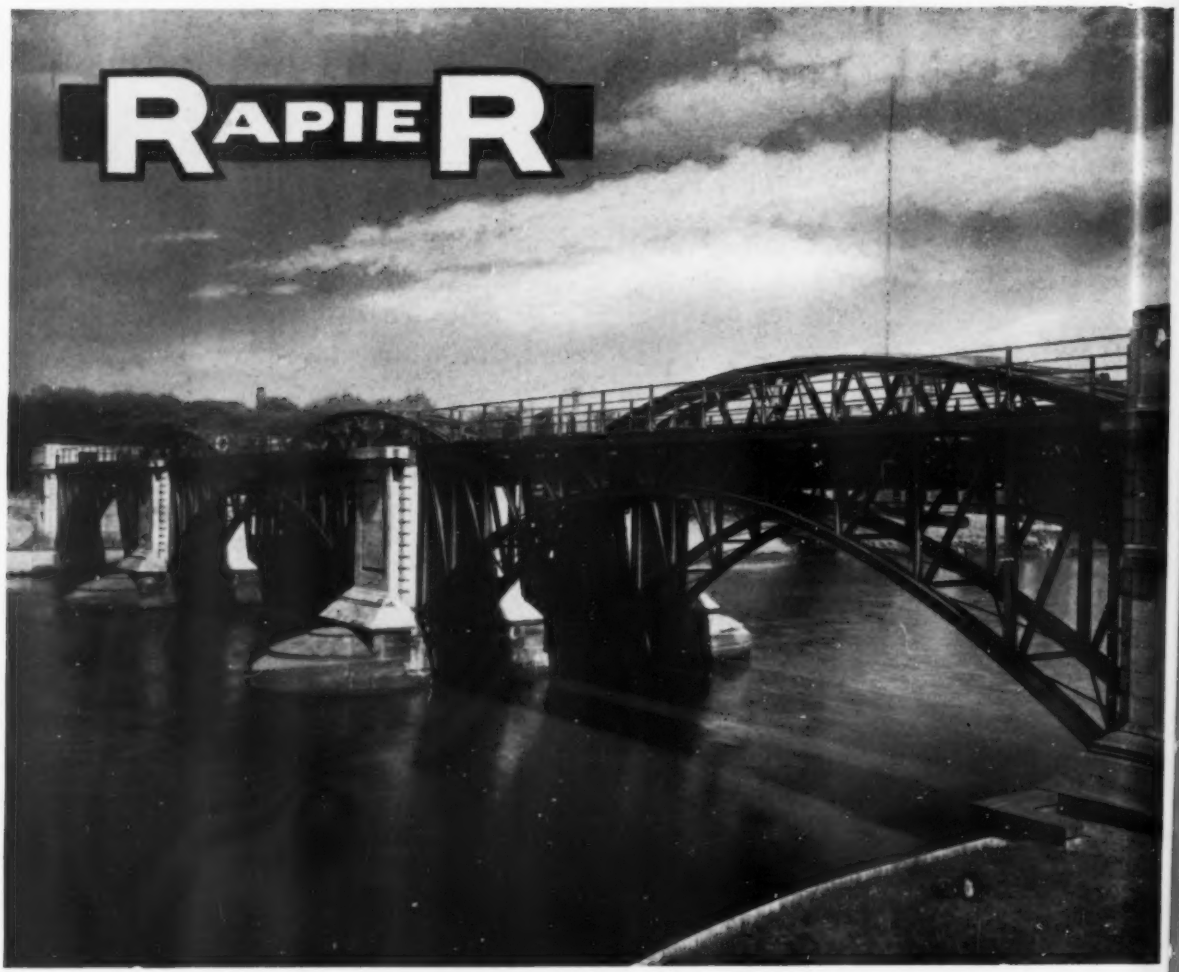

RapieR Gates control flood water and retain the high tide level on the River Clyde in Glasgow. The installation includes three 80 feet span gates, 12 feet deep with bridge work and electric operating gears. The gates automatically turn under the arches in the fully raised positions.

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Test runner used for Ets Neyrpic's study of n° 3 turbine constructed for the Kemano Power Station by Dominion Engineering Company

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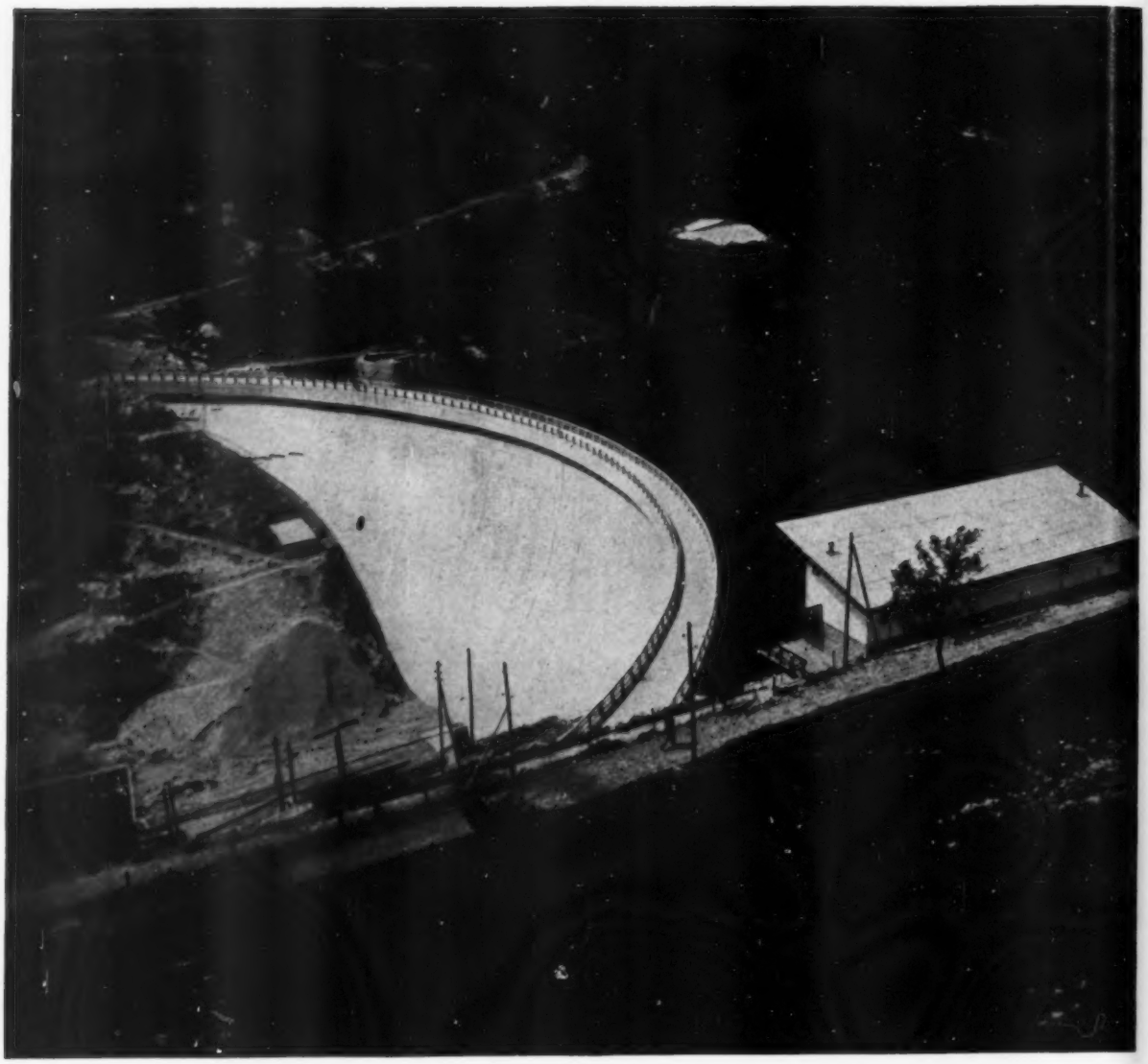

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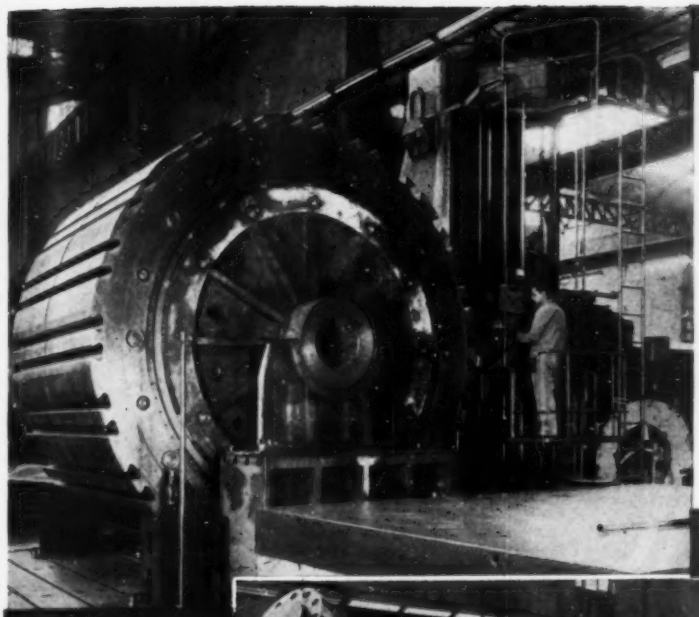

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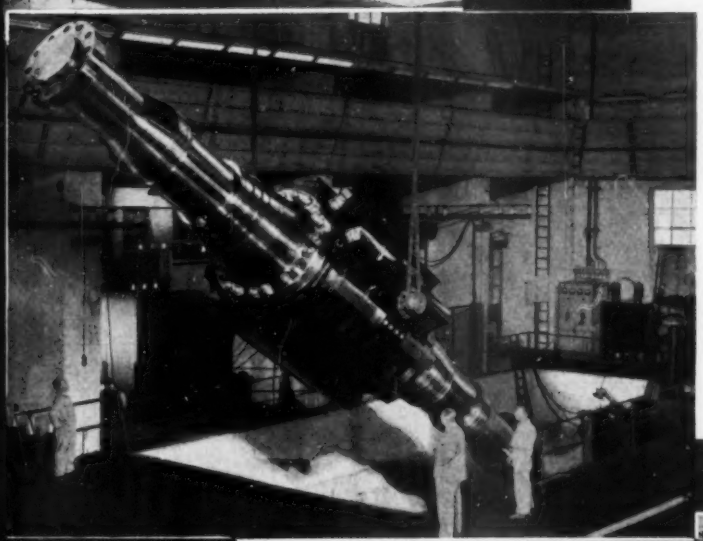
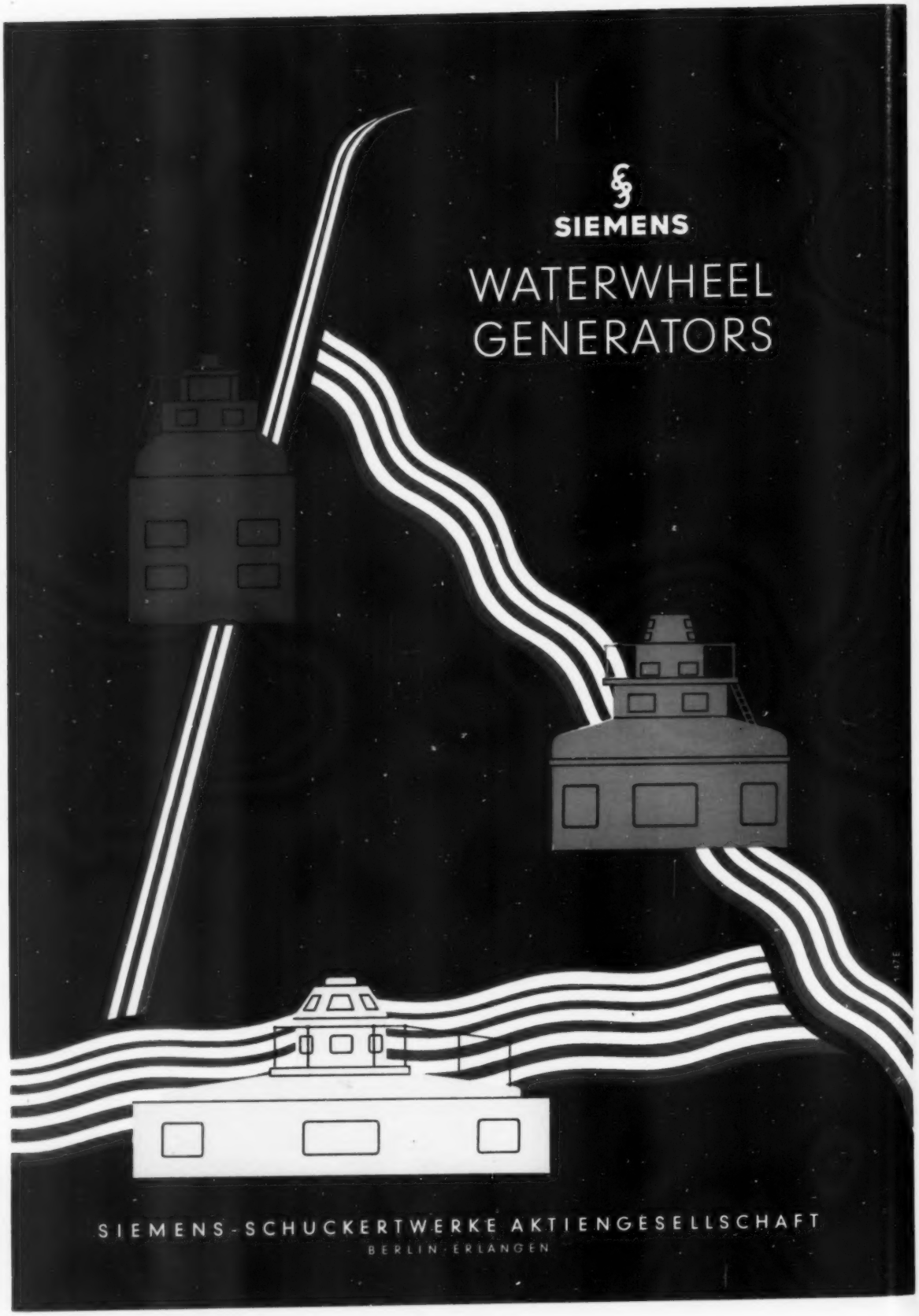


Rotor, shaft and stator for one of the two Water Wheel Alternators (110,000 kVA—13,800 Volts—300 r.p.m.—weight 650 tons) installed by Marelli in the Cimego Hydro-Electric Power Station of the Società Elettrica Bresciana (Italy). These alternators are believed to be the largest horizontal units yet built.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Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

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Owen Falls Many miles of power, distribution and control cables for the first section of this great scheme were supplied and installed for the Uganda Electricity Board by the BICC Group, who are also erecting 120 miles of 132kV overhead line to carry power to Tororo and Kampala.

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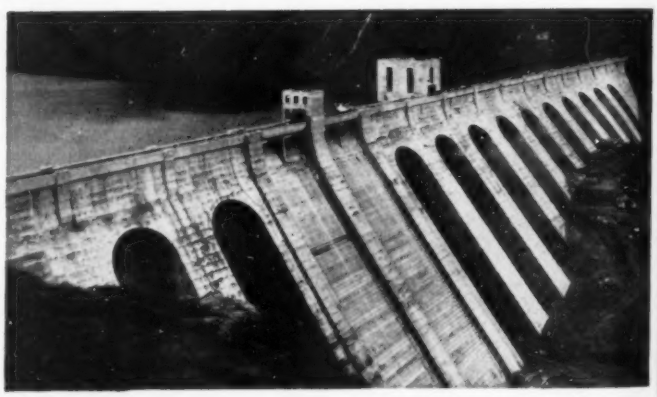

Loch Sloy This scheme is now connected with the Clachan power station of the Glen Shira Hydro-Electric Scheme by a nine mile single circuit 132kV overhead line. It was erected for the North of Scotland Hydro-Electric Board by the BICC Group. *Consulting Engineers:* Messrs. Merz & McLellan of London.

Los Peares At Los Peares, Spain, Fuerzas Electricas del Noroeste S.A. (Fenosa) have erected a dam and a 160,000kW power station. Approximately 20 miles of BICC multicore control cables were used in this contract. They were supplied through our agents in Madrid, Dugopa S.L., to the British Thomson-Houston Co., Ltd.—main contractors.

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Transmission-line Research

THE technique of harnessing almost any source of water power in as economical and efficient a manner as the conditions will permit, can be said to be well established. It may well be that the progress of civil-engineering technique will result in more economical designs for future hydro-electric installations and the mechanical engineers may well find room for improvement in the sluices, pipelines and turbines associated with future plants; but no fundamental problems remain to be solved in those fields, and moreover a degree of reliability in service for the civil-engineering and power-house equipment of such a high standard can now be said to have been reached that little improvement could ever be hoped for in that particular respect.

In regard, however, to the transmission lines which carry the current from hydro power stations (often in extremely remote areas) to the centres of industry and population where the energy is needed, there still remains much to be done before the same degree of all-round technical and economic perfection as that obtaining in the other engineering departments can be said to have been achieved. There is still room for much argument as to the basic system of transmission to be adopted. The protagonists of direct current are firmly of the opinion that much economy can be achieved by the use of this system, now that it has been proved in practice by the successful running of two commercial-scale schemes, one in Sweden and one in Russia, for well over a year. The converting equipment which forms the only novel feature of a d.c. transmission link has been developed to the stage where even the largest projects could satisfactorily be designed and manufactured. In the three-phase a.c. field, discussion is still taking place on many aspects of transmission technique, and no final state can yet be said to have been reached. For example, although a voltage level of 400 kV has now been satisfactorily achieved in several countries there is no definite, authoritative pronouncement from any source that this will be the ultimate limit. Many of the disadvantages of a.c. transmission have been countered by the use of series capacitors, and experience is now being gained in the use and operation of these devices for voltages up to 380 kV.

The continued developments taking place in the circuit-breaker field mean that new viewpoints are gradually being adopted in regard to the permissible short-circuit current allowable at particular points on a network, and thus new vistas of network design, involving redesigned transmission lines, can be taken into practical consideration whereas previously they may not have been regarded as feasible.

The actual physical design of overhead lines cannot yet be said to have been stabilised, when a world picture of progress in this field is inspected. The use of tubular towers filled with concrete, on the one hand, and the successful adoption of wood-pole supports for voltages as high as 220 kV, on the other hand, point to the two extremes of progress: first, in regard to pure technical efficiency, and secondly, to the highest possible economy in first cost.

The employment of single, duplicate or triplicate conductors for each phase wire is still a matter on which much experimental information is being gained, but one in which no final conclusions have yet been reached. The employment of very large spans for special purposes such as the Messina crossing, in Italy, the Kitimat and Jervis inlet schemes in Canada, and the proposed new Severn crossing in Great Britain, have resulted in special equipment being designed which, in the course of time, may well have its influence on standard equipment. Progress is still being made in "hot-line working," to avoid outages when maintenance has to be undertaken.

In the protective-gear field, the transmission engineers are making extended use of microwave radio and are also gradually developing automatic fault-finding equipment so that the very long time required for patrol men to be called out, transported to site, and left to cope with line inspection, under what may be very difficult tropical or arctic conditions, can be very greatly reduced.

The vital transformers which couple the generators

to the power lines can perhaps be said to have reached a degree of technical stability of design greater than that of any other components in the link between the generator and the user. There is still much research in progress, however, in regard to the better utilisation of the active materials within the transformer tank. The use of such devices as thermal images is enabling much greater knowledge to be obtained in regard to actual working conditions. The testing of transformer windings, in the last few years, by means of impulse-testing equipment has resulted in an even greater degree of reliability in service for the transformers nowadays installed; and this is particularly beneficial in view of the very large sizes of transformer unit now being supplied, which involve major transportation problems if such a unit has to be returned to works due to a fault.

Allied to the actual design and development of transmission equipment there has been a move, in recent years, towards acquiring much more detailed knowledge of the conditions obtaining on transmission systems when disturbances take place. The various large supply authorities, both in Europe and America, have devoted much time to the measurement of such factors as switching overvoltage values, rates of rise of restriking voltage, and fault-current flows, under various network conditions. They have been greatly aided in this work by the use of electronic calculators or computors, which the electronics industry is nowadays able to produce to assist them.

Taken as a whole, transmission engineers can nowadays carry the power almost from anywhere to anywhere; even long undersea links are not ruled out if high-voltage direct current can be employed. But perhaps they cannot yet say that, over a lengthy period of years, they can achieve the same standards of absolute reliability and complete lack of the need for lengthy shut-downs for maintenance (except under controlled conditions) which their civil and mechanical engineering brethren can claim nowadays in respect of practically all the world's hydro-electric power schemes.

B.C. Electric Expansion

IN announcing a construction budget for 1956 of $75 million, B.C. Electric is creating a new record, for this figure is nearly twice as large as that for 1955 and is by far the biggest for any year in the Company's history. When, towards the close of 1944, the Company announced a $50 million programme for post-war development, some doubts were expressed in some quarters as to the ability to raise the money, but during the past decade $290 million worth of electric, gas and transit facilities have been added to the Company's system, and it is believed that in the next few years the rate of expansion will be greatly increased.

As regards 1956, it is expected that the 58,500 h.p. Seton generating station will be completed by the autumn, and that by then the submarine cable link between the mainland and Vancouver Island will be in operation.

Work on the last 37 mile link of the extra-high-voltage line, which will give Vancouver and the Lower Mainland a completely separate second circuit to its largest source of power—the 248,000 h.p. plant at Bridge River—is now under way and should be completed this year. Clearing operations are going ahead on the right-of-way, which extends from the generating station, on Lake Seton, 100 miles north-east of Vancouver, south to Creekside, on the PGE railroad near Pemberton. There the new circuit will join the transmission line now under construction along the banks of Lillooet Lake and Lillooet River and on the west side of Harrison Lake. The latter terminates near Rosedale, where it will tap into the existing Wahleach line to the city.

The entire circuit will operate at 345 kV, and will be the first transmission line in Canada to do so. Instead of the conventional three-wire line, the new link with Bridge River will require six steel-core aluminium conductors. The 102 towers required for the final 37 mile stretch are being fabricated by Western Bridge Co. Ltd., in Vancouver, and will absorb over 1,000 tons of steel. When the line is completed, power from Bridge River and from the new Seton plant will travel to Vancouver simultaneously over two lines—the existing 230 kV circuit and the 345 kV Harrison Lake line. The cost of the line will be approximately $113,500 per mile for 37 miles, or $4,200,000 for the stretch of circuit between Creekside and the Bridge River plant on Lake Seton.

Norwegian Power for Sweden

THE question of exporting power from Norway to Sweden has been keenly debated for several years, and discussions have ranged from the export of power in principle to the establishment of financial arrangements fair to both countries.

Agreement has now been reached on the export of power to Stockholm from a new hydro-electric station to be erected at Ovre Nea, near Trondheim. The station will be built, owned, and operated by the City of Trondheim, and is expected to cost £5,900,000, of which £4,500,000 is to be raised by a loan in Sweden, repayable over 15 years. The annual output is expected to be about 600 million kWh, of which 330 million kWh will be exported to Stockholm at a price ranging from a maximum of 2·9 Swedish ore (nearly one halfpenny) in winter to half that amount in summer, the contract being for a term of 15 years.

The Swedish Government approved the scheme in March 1954, and the Storting (the Norwegian Parliament) gave its own approval by 81 votes to 63 towards the end of last year.

Persian Air Survey

AN air survey contract valued at about £250,000—one of the largest secured by a British firm—has been awarded by the Persian Government to the Air Survey Co. Ltd., a subsidiary of Fairey Aviation Company. Persian personnel will be trained in air-survey technique for a period of two years, and the work will embrace planning for developments of all kinds, including hydro-electric schemes.

Swedes Claim World Tunnel Record

TWO tunnelling crews at Sweden's Harrsele hydro-electric scheme near the Arctic Circle claimed a world record for a tunnel of the size in question when they broke through on December 21, two and a half months ahead of schedule. When the men met underground they had excavated 400,000 tons of rock and driven a tunnel 59 ft. high and 49 ft. wide for over

two miles. Best advance for one month, since the first round was fired in June, 1954, was 585 ft. The tunnel was driven by two crews working from opposite ends. Tunnelling was carried out by the Swedish method with Copco drills, manufactured in Sweden, each operated by one man working from a three-tiered drilling platform.

The power station at Harrsele will come into operation in the autumn of 1957.

Tenders for Waipapa

TENDERS are being called by the New Zealand Government State Hydro-Electric Department, according to Reuter, for the supply and delivery at Auckland of three 18,888 kVA generators and three 24,000 h.p. turbines for the proposed Waipapa power station on the Waikato river. Closing date for tenders is May 15, 1956. The Waikato river is the chief hydro-electric power source for the North Island. According to present information, the proposed station will have an output of 49,500 kW. Existing stations operating are Karapiro (90,000 kW), Arapuni (158,000 kW), and Maraetai (180,000 kW). Waipapa will be built between Arapuni and Maraetai. Two further stations are under construction, in Whakamaru (100,000 kW) and Atiamuri (63,000 kW). Four other stations are planned to harness almost the whole length of the Waikato river from its outlet (Lake Taupo) to within a few miles of the city of Hamilton.

French Order for Bersimis

THE last four turbines for the 1,200,000 h.p. Bersimis power scheme, being built by the Quebec Hydro-Electric Commission, have been ordered from Neyrpic Canada Ltd., sister company to the French firm Ets. NEYRPIC. The turbines will be manufactured partly in Grenoble (France), partly in the Montreal factory of Canadian Vickers Ltd. With a peak output of 176,000 h.p. under a maximum head of 875 ft., these machines are likely to break a world record. Erection will take place in 1957-58, in an underground station, which is situated in the forest area, 80 miles north of the St. Lawrence river estuary, and 300 miles north-east of the city of Quebec.

These turbines will drive the 138 MW alternators ordered from Metropolitan-Vickers Electrical Co. Ltd. last summer.

Norwegian Scheme

PLANS are being prepared for the development of the hydro-electric resources of the Otra river in South Norway, which is estimated to have a potential capacity of 400 MW. A number of sites are at present being examined.

Dalles Dam Transformer Contract

FERRANTI LTD. have been awarded a further contract by the Corps of Engineers, U.S. Army, for 21 large power transformers. The contract is valued at $2,080,940 (£746,000) and is the largest one for transformers so far to be placed in Britain by the U.S.A. It has been obtained in the face of exceptionally keen American, British and Continental competition. The contract covers eighteen 63,000 kVA 230 kV single-phase transformers and three 63,000 kVA 115 kV single-phase transformers for the Dalles Dam project, Columbia River, on the borders of Washington and Oregon. The transformers will be of forced oil, forced water-cooled, inert gas-filled type, and each will weigh approximately 73 tons. Delivery is to commence early in 1957 and be completed early in 1960.

This contract, the fifth awarded to Ferranti Ltd. by the U.S.A. in recent years, brings the total number of transformers supplied or under construction to 38 units of a total capacity of 1,972,000 kVA, and a value of $3,827,000 (£1,366,785).

Birsfelden Power Station Inaugurated

THE Birsfelden power station on the Upper Rhine, described in our February 1955 issue, was officially inaugurated on November 24, 1955. The generating equipment consists of four vertical 30,000 h.p. four-blade Kaplan turbines, each driving a 28,608 kVA generator at 68·2 r.p.m., at the designed discharge of 1,200 cu. m. per sec., the stators operate from a head of no more than 6·64 m., which involves a loss of head of 0·98 m. at the Augst-Wyhlen plant upstream. An interesting feature of the station is its unusual architectural design to bring it into harmony with its surroundings.

Swedish Order for India

DAMODAR Valley Corporation has just placed an order with Nydqvist & Holm Aktiebolag (NOHAB), Trollhättan, Sweden, for one Kaplan turbine intended for Panchet Hill hydro-electric power plant. The plant will be located in the Damodar river, 150 miles west of Calcutta. It is believed that the turbine will be the largest Kaplan in India, both with regard to output as well as dimensions. The net design head is 81 ft., at which head the turbine will develop 56,750 h.p. at 125 r.p.m. The head will vary between 66 and 113 ft. The diameter of the runner will be 17 ft. 8 in.

Alcan Repeat Order

THE English Electric Company Limited has received a repeat order for a water-turbine-driven alternator from the Aluminum Company of Canada for its underground power station at Kemano in British Columbia. The value of the order is $856,000. The rating of the alternator is 132,000 kVA. The placing of the order follows the successful operation of a similar alternator built at the English Electric Stafford works and delivered to Kemano two years ago.

Power in Sao Paulo

A FOUR Year Plan now under way in the State of São Paulo, Brazil, will result in an important access to installed capacity. According to *Brasil Moderno*, the 860 MW available in 1952 has already been increased to 1,105 MW, and in 1956 the 390 MW Cubutão plant and the 80 MW Rio Grande plant are scheduled to come into operation. A two-million horsepower scheme is also being carried out by Companhia Brasileira de Engenharia to harness the Tietè River and further to exploit the resources of the Paraíba.

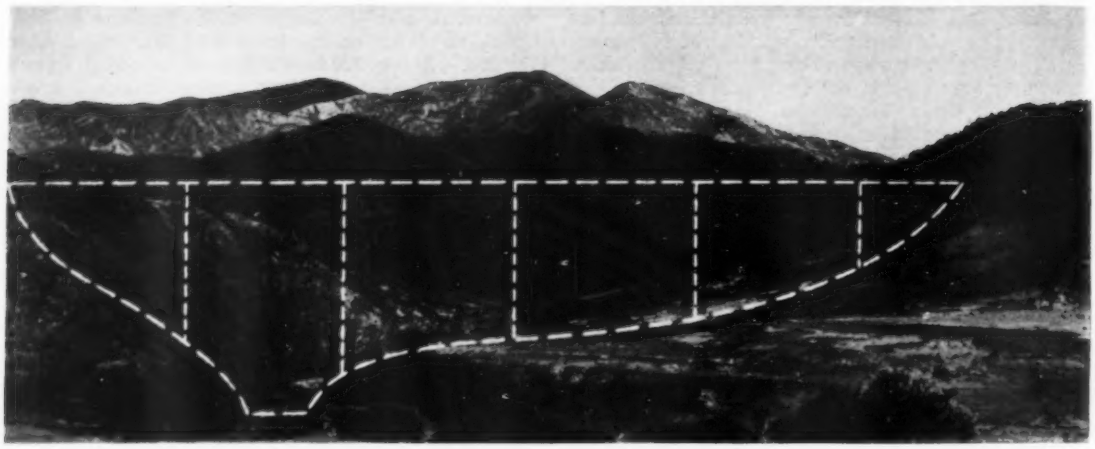


Fig. 1. Site of Erraguène dam looking downstream

The Upper Oued Djen Djen Project

This important Algerian development will have a capacity of 114 MW, and an ultimate output of 340 million kWh per annum. The scheme includes a buttress dam of novel design, a pressure tunnel incorporating an inverted syphon operating under a head of 205 m., and two power stations, the larger of which is an underground station discharging directly into the Mediterranean

By FRANCOIS CORDELLE* and MAX DURAND*

SINCE 1947, the production of electrical energy in Algeria has increased at the rate of 10·4 per cent. a year, reaching 827 million kWh in 1954, and the lowest rate of increase for the coming years is assessed at 10 per cent. Exceeding, as it does, the rate generally accepted for France herself, this estimate appears, at first sight, unwarrantable but is none the less justified by the substantial yearly increase of 2 per cent. in the population of Algeria and by the gradual narrowing of the gap between the Algerian and French standards of living. The means of production now available should enable Algeria to meet the increasing demand in 1956, but as early as 1957, to ensure the necessary peak output and cover the whole of the requirements in a dry year, it will be necessary, at peak periods up to 2,000 hours a year, to maintain in operation obsolete thermal plants which have been listed as "cold reserve" since 1954. In view of this serious situation and of the impossibility of initiating new hydro-electric developments at once, Electricité et Gaz d'Algérie, in co-operation with the French Navy, have decided to install at Mers-el-Kebir two gas-turbine-driven generating sets which will provide an additional capacity of 20 MW corresponding to the yearly increase in peak output. The problem of supply thus appears to be solved for 1957 but will confront the country with undiminished insistence the following year. The commissioning of new developments in the very near future is therefore imperative if Algeria is to be spared the calamity of a shortage of energy supply.

Exhaustive field investigations have been made with a view to selecting a development which would be ready for operation in 1958 and would guarantee the generation of the power necessary at peak hours of heavy winter load. In other words, since the available modern thermal plants and unregulated hydro-electric developments are capable of meeting normal requirements for a few more years to come, what is now wanted in Algeria is a plant provided with a substantial margin of additional capacity. The experience gained in French North Africa having proved that these conditions are particularly well fulfilled by hydro-electric plants operating with regulated storage, the choice finally fell on the development of the Upper Oued Djen Djen, a river section extremely favourable to the setting up of the necessary works and ensuring, above all, the possibility of storing 200 million cu. m. between an elevation of 600 and 670 m. in the best-watered district of Algeria, at only about 13 km. from the sea.

* Chefs de Service de Travaux d'Aménagements Hydro-Electriques à Electricité et Gaz d'Algérie.

Local Conditions and Hydrographic Data

The Oued Djen Djen rises in Little Kabylia in the massif of the Djebel Babor (2,004 m.) which overlooks the eastern shore of the Gulf of Bougie (Fig. 2); flowing first eastwards, it then turns sharply to the north, runs through chalky gorges and falls into the Mediterranean slightly east of Djidjelli. On its upper course, at a place called Erraguène, it offers an uncommonly favourable site for the erection of a dam, about 80 m. in total height and less than 500 m. along the crest, to create a storage reservoir 200 million cu. m. in capacity. The Erraguène catchment is but 133 sq. km. in area. In this fairly high mountainous region of Algeria the mean rainfall reaches 1,400 mm., which is twice as much as in the Paris region. The mean run-off exceeds 800 mm. and at Erraguène itself the average discharge of the Oued Djen Djen is over 110 million cu. m. per annum. A power station is to be placed at the foot of the dam, and from the tailwater basin a 13·5 km. tunnel will convey the power water to a penstock at a point dominating the village of Ziama-Mansouria and the sea, providing a head of 600 m. in addition to that of the power house at the foot of the dam. The magnitude of this head, the highest in North Africa, justifies a utilisation to the full of the advantages of the site and a thorough regularisation of the Oued, which, like all the other rivers of this country, varies widely in discharge, not only within one and the same year (70 per cent. during the four winter months) but also from one year to the other. For instance, in an observation period of 10 years, discharge measurements have fluctuated between 49 and 148 million cu. m. With a 200 million cu. m. storage, there is a more than 95 per cent. probability that this development will cover at least nine-tenths of the average yearly requirements in energy. The provision of generating equipment for an output considerably exceeding strict requirements warrants the profitability of the undertaking to a wide extent, since the consumption of that output is ensured.

On the other hand, the abundance of precipitation in the region and the operating head available have induced EGA to inquire into the possibilities of increasing the natural discharge of the Oued by diverting streams from neighbouring catchments. In a particularly favourable year, these diversions, to be carried out at later stages of the development, will raise the useful discharge from 110 to 230 million cu. m. and thus more than double the production figure. At the outset this figure is assessed, for an installed capacity of 114 MW, at 160 million kWh per annum corresponding to 1,400 hours of utilisation in a year.

The first stage of the Oued Djen Djen development comprises: the Erraguène dam, a power house at its foot, a regulating dam, the power-water supply system, and the main power house at Mansouria.

Erraguène Dam

The Oued Djen Djen, swollen at Erraguène by the junction of several minor oeuds (Bahar, El Gueroun,

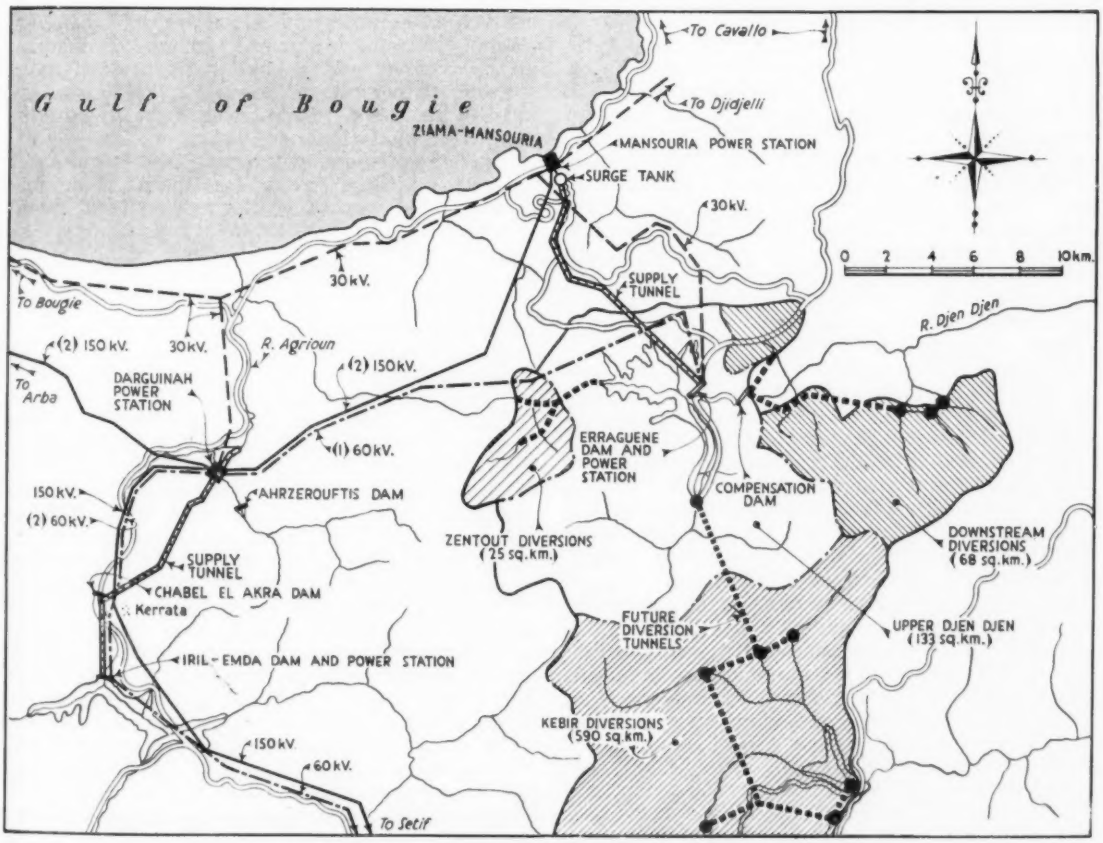


Fig. 2. Map of Algerian hydro-electric developments

Bou el Absat) subsequently enters the fairly deep valley it has cut in schistose rock. Judging from the meandering of its course and some general features of its cross section, this process of erosion has obviously taken place in stages. We have, in fact, the frequent occurrence of a convex bank overlooked by a fairly high cliff and of a concave bank formed by a slightly sloping shelf covered by alluvium, about 20 m. above the actual bottom of the oued, as occurs at the site of the dam. The gradient of the river bed is of the order of 1 : 100, and in spite of the substantial transportation of solid matter by the current, the rock mass of the bottom never ceases to be visible.

At a short distance downstream from the dam site, a small left-bank tributary, the Oued Zoundai, has dug a deep gully separated from the storage reservoir only by a relatively thin spur, the crest of which is slightly higher than that of the reservoir, except in one place, at right angles to a small col, which will be sealed by a 20 m. high subsidiary dam.

Geologically speaking, the whole of the Erraguène basin rests on siliceous schist of Lower Cretaceous age; the dam itself will stand on a narrow east-west syncline of calcareous schist (Middle Cretaceous), lying on siliceous schist. Both kinds of schist have an adequate mechanical resistance, and their permeability is very small. In view of the satisfactory stability of the foundation rock, any type of dam would have been acceptable, with the exception of a single-arch structure which is ruled out by the profile of the valley. In fact, the Selection Committee entrusted with the awarding of the contract appeared to favour two extremely differing solutions—a rockfill dam or a multiple-arch structure. In spite of its advantages, especially the ideal abutment of the left-bank cliff, the rockfill dam was rejected in view of the high transport costs resulting from the long distance between the dam itself and the only quarry from which suitable material could have been obtained. In point of fact, the lowest tender for a rockfill dam proved 35 per cent. higher than the lowest tender for a concrete structure, in spite of the cost of additional drainage in the left-bank abutment, and the margin of expenditure between the two solutions was further widened by the economy brought about by introducing certain technical features into the concrete dam.

The design finally selected was a multiple-arch dam, as shown in Fig. 3; it was worked out by M. Freyssinet, and submitted by Entreprises Campenon-Bernard. The most characteristic features are the "active abutments" at the downsream end of the buttresses, and the semicircular arches. Fig. 6 shows a single arch and its two adjacent buttresses. The "active abutments" consist of a set of flat jacks, made of steel plate, capable of exerting the reactions necessary to the stability of the structure (up to about 25,000 tons in the highest buttresses), and inserted between the heel of the buttress and an inclined fan-shaped footing which transfers those reactions to the ground. This principle, previously applied in Algeria at the Beni-Bahdel dam, enables the foundation of the dam to be divided into two sections separated by a wide strip of weakly stressed ground; the upstream section works under the usual conditions, while the downstream section, which includes the toe, permits the principal stresses to be concentrated at the back of the dam and below the general level of the foundation, these stresses being but moderately inclined to the horizontal. The slope of the footings, looking downstream, averages 1 : 2, and their lengths can be adapted at little cost to suit the ground. This arrangement results in a substantial reduction of the vertical component of the general resultant necessary to ensure the stability of the structure, leading to a reduction of the aggregate weight of water and concrete, and, at an equal batter of the upstream facing, to a very appreciable economy in the volume of concrete. The semicircular shape of the arches increases their transverse rigidity, and thus checks any buckling of the buttresses, it reorientates the resultant hydrostatic pressure in a direction to improve the general stability of the structure, it increases the load on the upstream edge of the foundations, and affects further economy in concrete.

The insertion of jacks between buttresses and footings permits the deflections corresponding to the normal working of the structure to be induced in advance, and for variations in these deflections to be detected in accordance not only with storage-level fluctuations but also with climatic changes. These changes, in fact, give rise to cyclic movements which are opposed by the structure to the extent of inducing distortions in the opposite direction. The "active abutments" enable these movements to be followed, as the heels of the buttresses afford a bearing surface perpendicular to the direction of stresses tending to induce sliding. In fact, the structure is stressed in the same way as a dam of traditional design, but this arrangement, in addition to reducing costs, enables the performance of the dam to be predetermined and hence increases its reliability; moreover, it enables delayed deformations in the concrete and ground to be detected more speedily, so that after a few years it will be possible to carry out a final readjustment of the structure in accordance with actual observations.

The Erraguéne dam will require 200,000 cu. m. of concrete and this, referred to the capacity of the storage reservoir it creates, gives a ratio of 1,000 cu. m. of water stored for each cu. m. of concrete used—an adequate proof both of the excellence of the site and the economy of the development.

Treatment of Foundation Rock

We have already mentioned the low permeability of the schists on which the dam is to be placed, but in spite of this a grout curtain will be laid down under the upstream toe of the dam. As the schist is very compact these injections will absorb very little cement, but they will at least seal off any possible faults.

These injections are intended equally to localise pressure losses along the contour lines. This is especially important in the case of the left bank, which might be subjected to an internal water pressure that might affect its stability. Even so, the low permeability of the rock introduces the risk of a build-up of pressure, and for this reason a drainage system will be constructed parallel to the grout curtain and downstream of it in the region of the toe of the left bank. By this means any stresses due to water pressure are confined to a region where they cannot be dangerous.

This treatment of the left-bank foundation rock will be supplemented on the surface by regrading the bank and by strengthening the foundations of the left-bank buttresses by footings placed on the surface of the regraded ground and provided with flat jacks similar to those of the active abutments.

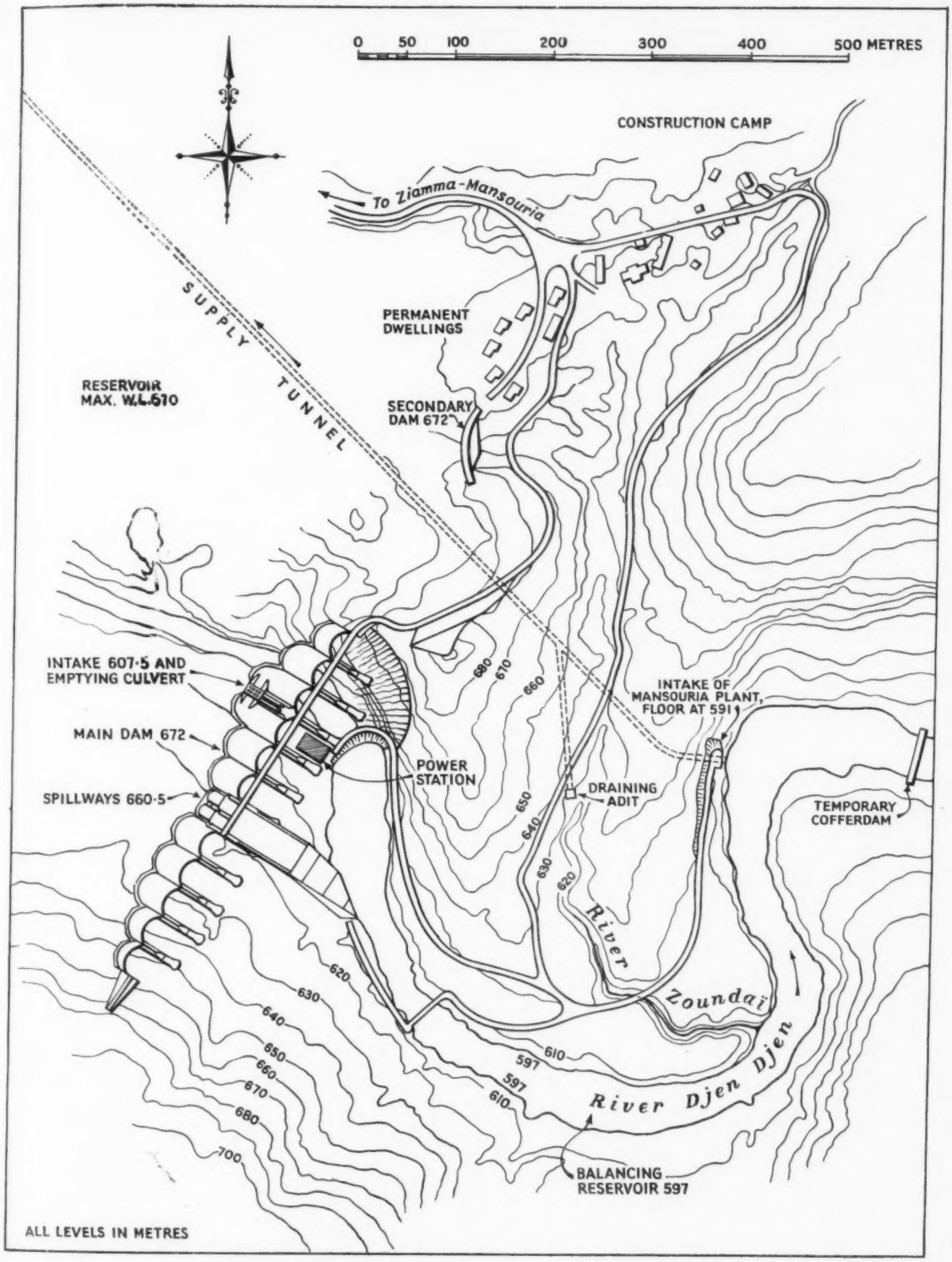


Fig. 3. Plan of the Erraguène dam and associated works on the Oued Djen Djen serving the Mansouria underground power station on the shores of the Mediterranean

Fig. 4. View of left bank of Erraguène dam site

Ancillary Works

The spillway, situated a short distance from a minor bed on the right bank, will consist of two openings between three special buttresses spaced at 17·5 m. centres, *i.e.*, at half the spacing of the normal buttresses. Each section will be controlled by an automatic taintor gate, and water will return to the Oued through a channel passing first over the downstream face of the buttresses, then in the rock, and terminating with an energy dissipator. The spillway, designed on the basis of model tests made at the Chatou laboratory, is to cope with a maximum discharge of 1,500 cu. m. per sec.

The bottom outlets consist of two 1·6 m. diameter culverts, each closed at the upstream end by a stoplog handled from the crest of the dam, and upstream and downstream by a servomotor-controlled sluice. These four sluices, each 1 m. wide by 2 m. high, are designed to exert a pressure of 120 tons on the sill, so as to ensure their closure whatever the nature of solid matter that may enter the culverts. In addition, two separate small conduits, 0·4 m. in diameter, each fitted with a small sluice, act as bypasses to the main downstream sluices. The purpose of these sluices is to evacuate the density currents or underflow, the waters of the Algerian Oueds being heavily loaded at flood periods with solid matter which silts up reservoirs. This desilting system was adopted after a series of systematic tests, carried out in part in the Oued Djen Djen basin itself, had proved that these density currents do not mix with the clear water of the reservoir but travel along the bottom, depositing the coarse matter only. This underflow, however, can be drawn off only to a limited extent if losses of clear water are to be avoided. At the Iril Emda dam of the Oued Agrioun development, an arrangement of this type, which deals with water frequently reaching 1·080 in density, evacuated in less than a year over one million cu. m. of solid material at the cost of a very small loss of power water.*

The intake, placed immediately above the outlet culverts, can be closed by the same stoplog as the culvert. A finescreen and a trashrack complete its equipment.

Erraguène Power Plant

The power house will be located at the foot of the dam between two of the buttresses on the right bank of the minor bed. This layout enables the length of the penstock and of the outlet culverts to be reduced to a minimum, ensuring at the same time easy access for vehicles conveying heavy pieces of equipment. A suggestion to erect the power house in the minor bed itself was rejected in order not to interfere with the flow of the Oued while work was in progress. The generating equipment is restricted to a single vertical-shaft set which consists of a 16,000 kVA alternator driven by a Francis turbine running at 375 r.p.m. and capable of coping, under any head between 35 and 75 m., with

* An article, "New Methods of Sediment Control in Reservoirs," by H. Duquennois, Chief of the EGA Research Organisation, will be published shortly.

Fig. 5. View of right bank of Erraguène dam site

a discharge of at least 20 cu. m. per sec., corresponding to the rated output of the whole development. The capacity of the alternator corresponds to the power output of the turbine when absorbing this discharge from the minimum head. This means to say that the turbine is overpowered in comparison with the alternator, and when working from a head of upwards of 45 m., will have to operate at restricted gate opening.

The energy output of the Erraguène plant will be transmitted to the Darguinah substation by a 60 kV line. The ancillary machines can be supplied either by a transformer fed from the busbars of the alternator, or from a 30 kV line connected at Mansouria with the local distribution system and serving the construction site, or in cases of emergency, by a relief generating set. The equipment of the Erraguène substation, which is adjacent to the power house, consists of a single transformer connected solidly to the alternator, and of a single circuit breaker. The whole of the power plant will operate automatically.

Regulating Dam

At later stages of the development, when the downstream tributaries of the Oued are to be diverted, the provision of a balancing reservoir is contemplated. For this purpose, a dam 30 m. high will be erected on the Oued Djen Djen about 2 km. downstream from the main dam. At the initial stage, the duties of this auxiliary dam will be assumed by a temporary cofferdam set up immediately downstream from the intake of the power tunnel of the Mansouria plant. This cofferdam, about 10 m. in height, will be fitted only with an emptying and desilting gate, and its free spillway will be designed for the same flood discharge as the main dam. The storage capacity created by this cofferdam will enable the two plants at Erraguène and Mansouria to operate for periods of as much as two hours at the maximum discharge of 20 cu. m. per sec.

Water-Supply System

The whole of the head of about 600 m. available between the discharge from the Erraguène turbine and the sea will be utilised by the Mansouria power house. This will be situated on the shore of the Mediterranean, at the foot of the 800 m. peak of the Djebel Brek, which the Djemâa Col practically cuts off from the main range of the Djebel Tloudène. The supply system of the Mansouria plant is therefore divided into three sections (Fig. 7): a 10,400 m. tunnel driven through the Djebel Tloudène, a 1,800 m. inverted syphon across the Djemâa Col, and a 1,300 m. tunnel through the Djebel Brek between the downstream end of the syphon and the surge tank standing at the head of the penstock.

The Djebel Tloudène Tunnel begins from an intake situated 500 m. downstream from the main dam, in a loop of the balancing reservoir acting as a tailrace to the Erraguène plant. This position is particularly favourable to the layout of the tunnel as it keeps the intake works at an adequate distance from the Erraguène spillway, avoids driving the tunnel through the left-bank abutment of the main dam, and increases the useful capacity of the balancing reservoir by lowering its minimum operating level. The final layout of the tunnel was determined after an exhaustive geological survey supported by exploration borings. The tunnelling work will proceed from three construction adits, which, upon completion of the development, will be converted into drainage and inspection galleries. The inclined adit nearest the intake is 200 m. in length. The Oued Ahriri adit, 7 km. farther downstream, has only a slight slope and its length of 400 m. has been

dictated by geological considerations affecting the course of the tunnel. The third adit is only 100 m. long. The tunnel, concrete lined throughout, has a circular cross section and is 3·4 m. in diameter. The lining is normally 30 cm. thick but in the Triassic zone, a few 100 m. in length occurring between the upstream and downstream zones of partly siliceous schist and partly Liassic calcareous rock, a plain-concrete outer lining, 25 cm. in average thickness, is to be strengthened by an inner 10 cm. layer of concrete reinforced at the rate of 500 kg. of steel per linear metre.

The Djemâa Col Syphon is a conspicuous feature of the Mansouria supply system, imposed, as it is, by a topography which makes it impossible to maintain the tunnel at an elevation close to the piezometric line, and thus keep it subjected to but slight pressures. The problem confronting the authors of the project was to cross the Djemâa Col by means of a 1.800 m. long syphon, with a head of 205 m., laid underneath a steeply flanked pass in difficult ground. The solution adopted takes into account all topographic and geological conditions, as well as hydraulic, operating and economic requirements. To mention one particular point, before selecting for the syphon itself, for reasons of economy, a smaller diameter than for the adjacent tunnel sections, tests were carried out in order to make sure that these variations in diameter would not induce any resonance or dangerous overpressures.

The syphon consists of a conduit of prestressed concrete sections, each 3 m. in length and capable of resisting the maximum pressure occurring in practice. It is reinforced throughout by a watertight lining on the Bonna system. The selection of this type of conduit was made not only for reasons of economy but also in consideration of its imperviousness and resistance to corrosion. The very poor quality of the rock in the col (crushed schist and Trias) admitted of no leakage whatsoever, and this poor quality, which was particularly marked in the upstream section, in addition to the danger of erosion and superficial movement, subsequently led to a decision to lay the conduit entirely underground, contrary to the solution first contemplated. The tunnel itself will be strengthened by a lining, since the nature of the rock is such that it does not permit a safe excavation to be anticipated. Upon completion of the joints between the conduit sections, cement mortar will be injected into the 5 cm. annular space between the conduit and the tunnel. Three adits are contemplated, one at either end of the syphon and the third in the middle of the horizontal bottom section, to give access to the working faces and afford means of transporting the conduit sections. The bottom adit will be fitted with drainage arrangements.

Surge Tank and Penstock

The surge tank calls for no special comment. It is of the two-chamber type with an intermediate shaft 3 m. in diameter, and approximately satisfies the Thoma condition. Except for the upper dome at ground level, the whole structure is built underground.

The penstock consists of a steep steel-lined shaft. In

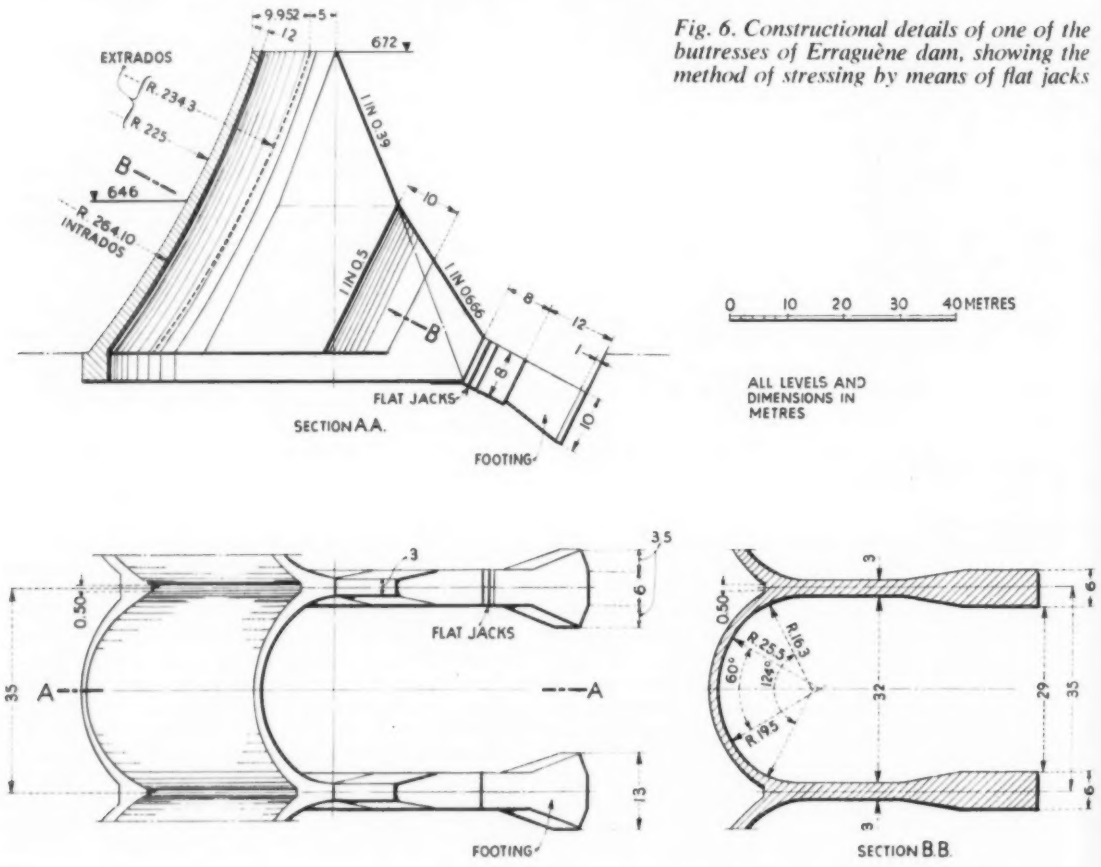


Fig. 6. Constructional details of one of the buttresses of Erraguène dam, showing the method of stressing by means of flat jacks

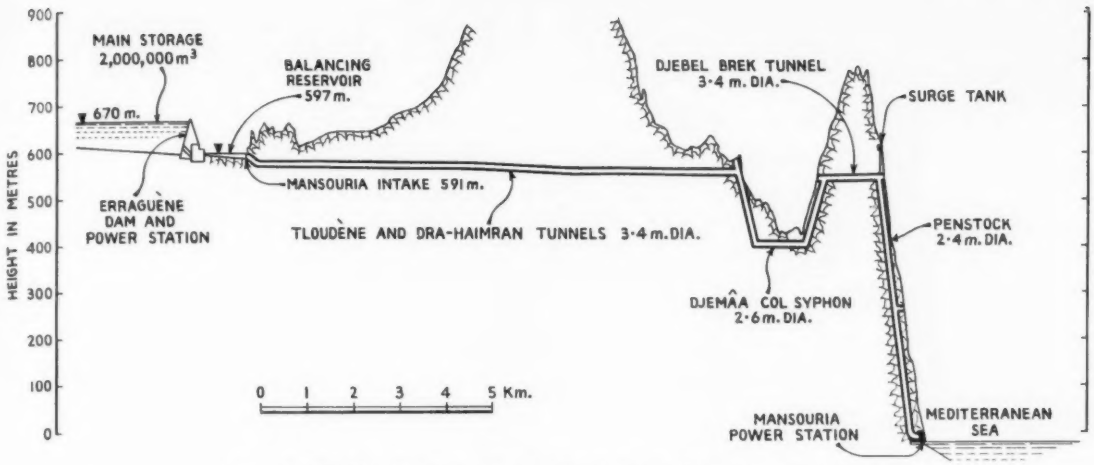


Fig. 7. Profile diagram of the Oued Djen Djen development

view of the excellent quality of the rock and the thickness of the superincumbent layer (80 m. as a minimum and frequently reaching 200 m., particularly in the lower section), it has been decided to investigate the possibility of concentrating in the rock itself practically the whole of the stresses resulting from water pressure. Resistance and distortion measurements on site will enable those lengths suitable for a thin steel lining to be singled out. According to the results of these tests, the penstock will be made either of 8 mm. mild-steel boiler plates suitably anchored in the concrete backing, or of medium-hard steel plate of the usual type calculated as if it were to be stressed to the limit of its elasticity either with or without the assistance of the superincumbent rock. Construction work on the penstock will proceed simultaneously from both ends and from an intermediate adit. In addition to an almost vertical section 850 m. in length, it will have a horizontal section about 100 m. long, with a diameter of 2·42 m.

The Mansouria Power House

The Mansouria power house, shown in plan in Fig. 8, will house two 57,700 kVA generating sets, each driven by two two-nozzle Pelton wheels overhung on the ends of the alternator shaft, and running at 428 r.p.m. At full load, each set requires a discharge of 10 cu. m. per sec. Apart from the uncommon layout of its electrical connections, the most peculiar feature of the Mansouria plant lies in the fact that it is built, together with its transformer station, entirely underground, although its turbines discharge into the sea. Any other solution was indeed ruled out by the topography of the site. Thanks to the absence of tides, it was possible to place the floor of the machine hall at no more than 6 m. above sea level, thus utilising the maximum head available. At this juncture, however, two serious problems arose:

(a) Protection of the tailrace outlet from the swell, and damping the wave effect in the tailrace and in the turbine pits.

(b) Excavation and construction work below sea level at a place where the cracked calcareous rock excludes any possibility of dewatering.

Tests affected on a small-scale model of the outlet structure of the tailrace led to a solution of the former problem, whereas the latter difficulty was evaded by simply avoiding excavation below sea level. In fact, with the single exception of the turbine pits placed at an elevation of 1·25 m., no work other than the tailrace has its floor or sill below an elevation of 3 m.

From the aspect of civil engineering, the underground power house consists of three main parallel chambers:

(a) The valve chamber, which contains the manifold distributing water to the four turbines, and the main control valves of the turbines. The tailrace extends to this chamber, thus ensuring ample protection from flooding.

(b) The machine hall, with the generating sets and their mechanical and electrical governing systems. Looking downstream, the built-up left wing of this hall has several floors housing the control room, relays and ancillary equipment. The right wing forms an erection bay. Two 80 ton travelling cranes are provided for handling the equipment. The floor of this gallery, laid at an elevation of 6 m., covers a basement containing, as far apart as possible, hydraulic and electric gear.

(c) The substation houses the transformers, in separate cubicles, as well as the circuit breakers and other 150 kV equipment.

Each of the main generating sets is connected directly with the Darguinah substation, 25 km. away, by a 150 kV line. The connection between the portal carrying the outgoing conductors and the underground substation is effected by means of oil-filled cables passing through a shaft about 70 m. high. There are no busbars in the station to interconnect the two generating sets.

In view of the prime importance of the Mansouria plant as a source of energy supply for Algeria, the utmost care has been devoted to the ancillary equipment, with a view to restricting to a minimum the risk of failures which might bring about a complete stoppage of the plant. For instance, the electrical layout is divided into two fully self-contained units, high tension as well as low tension, so that a failure in one of the generating sets will in no way whatsoever affect the running of the other.

Each main generating set provides its own auxiliary power, independently of local sources (30 kV system),

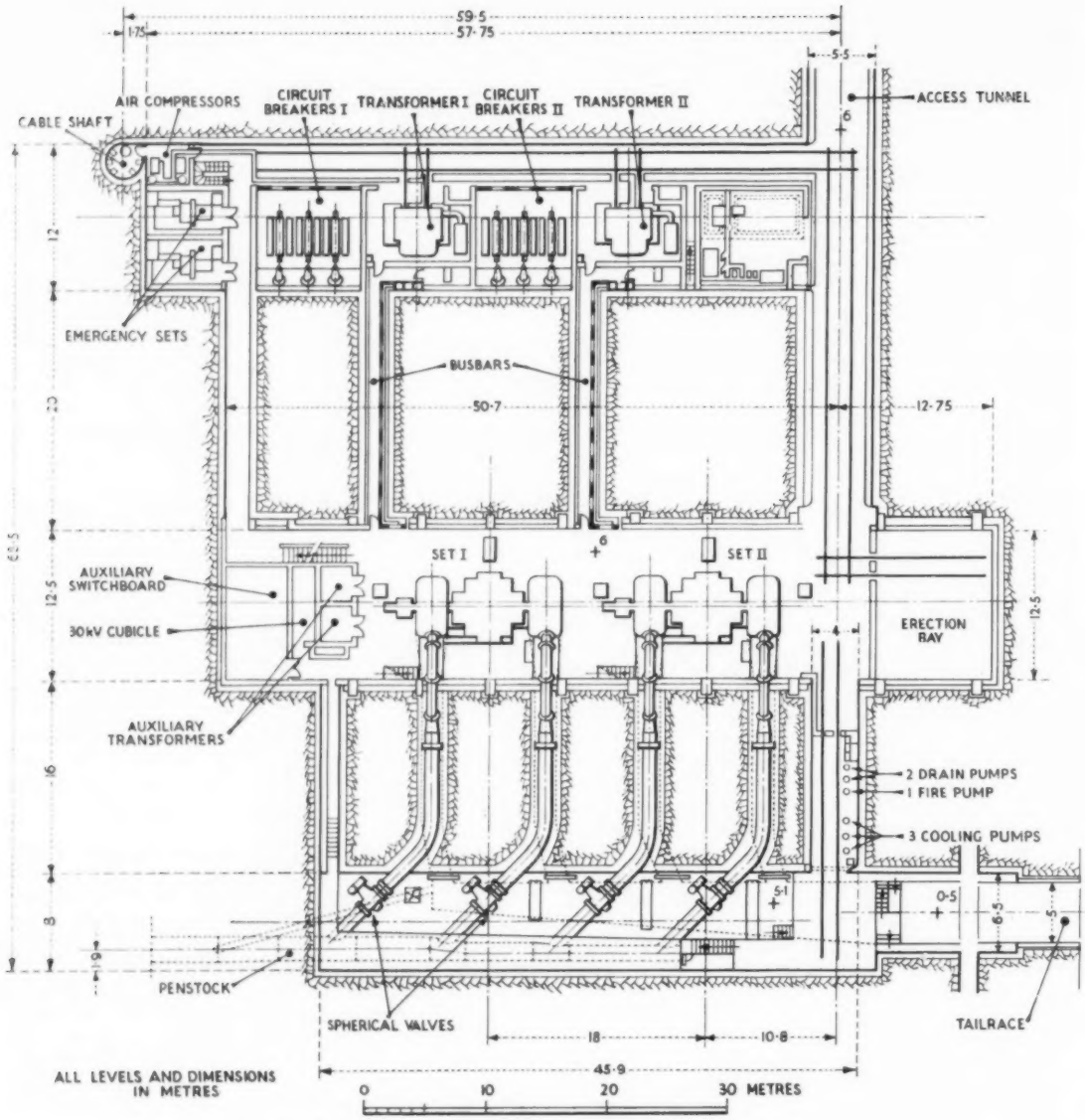


Fig. 8. Plan of Mansouria underground power station

by means of an auxiliary generator fitted on the end of the shaft extending from the near-side turbine. The ancillary machines which are common to both generating sets are restricted to those which may affect continuous running only after a length of time exceeding 30 minutes (cooling-tank feed, battery charging, etc.). To ensure, however, the indispensable degree of dependability of the plant, and secure its starting in the case of such contingencies as a total and protracted failure in the local system, there are two independent 200 h.p. generating sets, erected in two separate cubicles, which, together with the air-compressor room, form an extension of the substation.

With the exception of ancillary machines performing duties common to the whole plant, the Mansouria power house is therefore a double plant with two identical 50,000 kW units, fully independent of each other and both coupled to the Darguinah interconnecting station, which, so to speak, constitutes the focal point of the East-Algerian grid. In spite of their moderate length, these two Mansouria-Darguinah lines are fitted at both ends with circuit breakers which guarantee the possibility of quick reclosing in the event of short-duration mishaps. This additional precaution is thoroughly justified by the vicinity of the sea, the frequency of storms and the necessity to maintain an uninterrupted supply of current to consumers.

Work on the first stage of the Djen Djen development began some time ago, and is scheduled to last four years. Algeria will then be in a position to avail herself, at peak periods, of an additional capacity of 114 MW and a production of 160 million kWh. Upon its full completion, that is to say once the streams of the neighbouring catchments have been diverted and harnessed, the aggregate yearly production will rise to 340 million kWh.

High-Head Sluice Gates

Modern trends in the design of high-head gates in closed conduits are discussed and the author* describes a new design for which he claims substantial advantages

By ERNST HAASE

SINCE the end of the last century the design and construction of gates for hydro-electric plants and irrigation purposes, together with all other technical achievements, has followed a path of systematic evolution. In particular, development in the field of high-head gates during the last four decades has been especially remarkable. The height of the dams has increased more and more, and so have pressure heads, the size of outlets and the diameters of penstocks. During this period, the problem of controlling or shutting off the flow of water through large conduits has been approached from different angles, and a great number of gate types have been developed.

Better knowledge about hydraulic phenomena, stress flow in steel structures, better materials and greater experience have enabled designers to build better and more economical gates. Conditions and human taste as to what looks good and what does not, alter continuously. No designer can therefore claim that a particular gate design has reached a stage of finality, but there is one exception—the radial gate when used as a crest gate. For this type of gate hydraulic conditions are good, its construction is simple and economical, and it is fairly well suited for the average conditions.

On the other hand, no known type of high-pressure gate in a closed conduit is similarly far advanced and meets so well the hydraulic conditions as the radial type when it is used as a crest gate.

Basic Requirements

What are the conditions that the regulating gate in a closed conduit has to fulfil? These are:—

(1) When the gate is fully opened, the outlet should be a hydraulically smooth pipe, round or square in section, in order to achieve the highest possible discharge coefficient. No air should be passed into the conduit.

(2) When the gate is partially opened, the floor of the conduit and the lower parts of the sidewalls which are not already covered by the lowered gate, should be smooth. Air should be supplied.

(3) The whole arrangement should be simple and rigid, and in order to be economical it should be a fabricated steel structure instead of a cast and machined structure.

(4) Basic principles of economical hydraulic steel structure design, such as small number of moving parts, sealing frame in one plane on the upstream side of the gate in order to inspect wheels and stuffing box when the gate is closed, and good maintenance arrangements, should be provided.

Characteristics of Various Types

Slide Gate: The oldest type of gate in a conduit is probably the slide gate. It is often used as an emergency gate upstream of another gate which does the regulating. Formerly the gates were used as emergency gates against heads up to 250 ft. and as regulating gates against heads up to 90 ft.; but nowadays these gates are also adopted for higher heads.

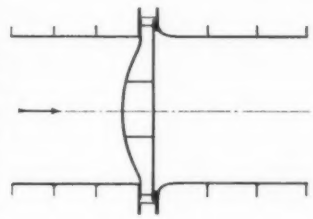
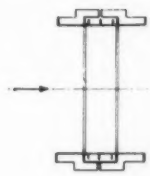
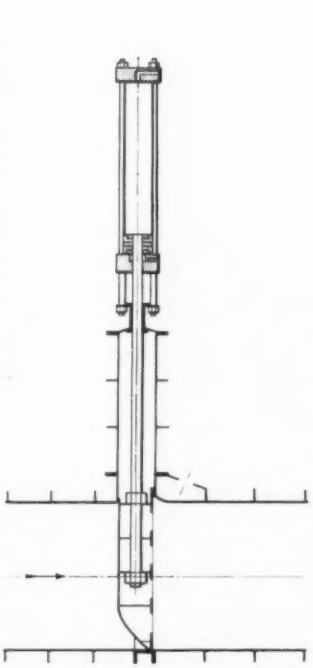


Fig. 1. Slide gate.





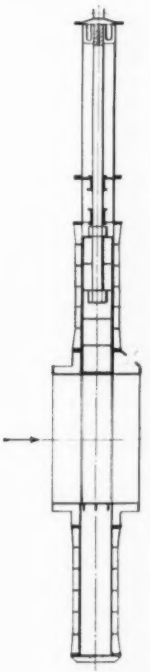


Fig. 2. Ring-follower gate

As shown in Fig. 1 a slide gate consists of the gate frame, which is arranged to form a vertical slot or recess in the walls on each side of the water passage, within which the gate leaf is received, supported and guided in its opening and closing movements. The leaf is usually provided with bronze seal bars on its down-

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stream face which rests, when the gate is closed, upon similar bronze seat bars of a different composition attached to the downstream sides of these slot walls. The full water load against the upstream face of the leaf is carried to its seal bars and transferred to the seal bars on the gate frames, and in consequence whenever the leaf is moved upward to open the gate or downward to effect closure, the leaf seal bars act in a manner similar to the runners on a sleigh, and are thus forced to rub or slide upon the mating surfaces of their supporting seal bars which are attached to the gate frames.

Slide gates are usually operated by a hydraulic hoist bolted to the bonnet cover. Since the dead weight of the gate is not able to overcome the friction of the partially loaded gate, the hoist has to push the gate into the closed position.

Due to its simple set-up, this type of gate was the first one to be installed as a high-pressure gate. When first used no air vent was provided behind the gate and the gate was apt to vibrate, especially at partial openings. Later, when slide gates with air supply were put into service the expectations again were not fulfilled. The gate designs in common use at that time had a nearly horizontal bottom with the seal on the downstream side of the gate leaf. Even at relatively low heads it was found that, with the gate partly open, there was a tendency, within a narrow range of part opening, for the control orifice to alternate between the upstream and downstream edges of the leaf with resultant heavy vibration and development of partial vacua on the underside of the leaf. With higher heads, cavitation pitting might appear on this underside, and should the gate be left for any lengthy period in the critical range of opening, this pitting might reach a stage where the safety of the leaf was threatened.

The principal change in slide-gate design to permit regulating service at higher heads, has been a change in the bottom of the gate leaf. The upstream face of the leaf is cut back so that the control orifice remains at all times at the downstream edge, and there is no wide area over which negative pressure can exist. With the conciliation of the control between the leaf edges, it is believed that these gates can be used at heads up to 200 ft. or more.

If the design of a slide gate is sound and if the gate leaf and the embedded parts can be maintained, and also if conduit size and pressure head are not too big, the slide gate will give a good performance due to its simple arrangement and robust design. For larger openings and greater heads, the unusually large hoist required makes the gate uneconomical. Also the adverse hydraulic conditions due to the unavoidable grooves cannot be neglected.

Roller and Wheel-Mounted Gates: The name "fixed-wheel gate" describes practically any structural-steel gate mounted on wheels but more often it identifies gates for relatively high heads used on the inlet end of penstocks and river outlets and at the entrance of and within tunnels. Fixed-wheel gates are usually made of structural steel and consist primarily of a skinplate mounted on horizontal beams which are supported by vertical girders that transmit the water load on the gate to tracks attached to the concrete supporting structure. The wheels are fixed in their relative positions with respect to the gate, just as the positions of the wheels of a railway car are fixed relative to the car itself.

The wheels substitute rolling friction for sliding friction, which usually allows the gate to be self-closing. The wheel shafts are located between the main horizontal beams and are either supported by two vertical members of the frame or by pedestal bearings bolted to the frame.

On small low-head gates, double-flanged wheels are used to guide the gate while moving under load. On larger gates, wheels without flanges are used. In the latter case spring-loaded guides are provided at the sides of the gates in addition to disc springs at both sides of each wheel. This arrangement forces the gate and each wheel to its central position whenever there is no water pressure against the gate, and allows lateral movement when the gate is moving under load without an excessive amount of friction.

The wheel bearings may range from oil-lubricated bronze sleeves or self-lubricated bushings with holes to form suitable recesses for filling with lubricating compound, to anti-friction-roller types, depending on the pressures and the allowable coefficient of friction to make the gate self-closing. Self-lubricated bearings are simple and allow a high bearing load. They work reasonably well as long as the gates remain normally submerged, but when the gates are exposed to the atmosphere for much of the time, there is a tendency for dust and grit to gather on the bearing surfaces and remove the graphite lubricant, with consequent increased friction and wear.

Roller-chain-mounted gates submerged for long intervals in scale-forming waters have been found to have their links encrusted until they could not articulate properly and so allow the rollers to pass around the ends of the raceway tracks, and thus became inoperative.

The simplicity of the wheel-type mounting allows a ruggedness of design which largely overcomes these objections. The moving parts are fewer and consequently less costly to machine. The tracks on the gate frames for wheel-type gates are usually less expensive than those required for the roller-type gates. They are likewise easier to install and align.

On account of the low coefficient for rolling friction, gates moving on Stoney-rollers have been extensively used. They still have some advantages in this respect, although the development of low-friction roller bearings has made it possible to substitute the more simple fixed-wheel gate.

By locating the skinplate and seals at the upstream face of the gate and raising the bottom beam of the gate so that the water jet parts contact with the gate at its upstream edge, vertical forces due to the water, such as downpull, buoyancy and water load on the top of the gate, can be practically eliminated. This arrangement has the additional advantage that when the gate is closed the well remains free of water and thus inspection and regular maintenance of the wheels, hoist and other parts of the gate can be carried out. Adequate venting to the atmosphere has to be provided on the downstream side of the gate through air-inlet pipes.

The largest number of high-head gates capable of part-opening operation in closed conduits belong to the category of fixed-wheel gates (including roller-mounted gates). The hoist capacity required by a fixed-wheel gate is considerably smaller than for a slide gate; this feature alone makes it superior to the slide gate. Experience with a large number of installed

fixed-wheel gates has given exact knowledge of the forces acting on them and how to counteract these forces by the employment of flexible or retractable seals, and elastic lateral or counterguide devices with preloaded springs.

The design of fixed-wheel gates has been further improved by using eccentric pins and disc springs for the wheels, by crowning the track, and in the latest developments by providing a so-called maintenance chamber around the gate in the raised position which allows easy inspection of the gate, wheels and seals, and, if necessary, their replacement. Another improvement has been to split the gate into units, each unit having at each side two wheels; the units are so joined together that the gate body as a whole is semi-flexible, and thus compensates inequaltiies of the track and permits even bearing under load.

All these improvements have helped to make the fixed-wheel gate a comparatively dependable high-head gate suitable for regulating the discharge in a closed conduit.

However, these developments have not been able to eliminate one bad feature—the open vertical slots which are common to all conventional high-pressure slide and fixed-wheel gates. These slots on each side in the walls of the water passage are exposed to high-velocity flow. For a head of 300 or 400 ft. of water the velocity in the conduit is in the range of 150 ft. per sec. Broadly, it can be said that when water flows in a conduit under such a high velocity the walls have to be smooth and no offset can be tolerated.

Ring-Follower Gate: This essential feature of smooth, continuous water passage surface is effected in the ring-follower gate by attaching a metal ring, of the same internal diameter as the conduit, to the under edge of the gate leaf and so positioning it that when the leaf is raised to the open position the interior surface of the ring is aligned with the circular wall surfaces of the water passage on either side, as is seen in Fig. 2.

The Paradox gate and the ring-seal gate also belong to the family of ring-follower gates. The principles of these three gates are the same; they differ only in being roller- or wheel-mounted and in the arrangement of the seal.

Gates of the ring-follower group provide circular waterways with practically unbroken flow surfaces by means of ring-follower members beneath and attached to their leaves. They likewise have bonnets extending beneath their conduits to receive their ring-follower members when their leaves are lowered for closure, and are also provided with air inlets in the upper portions of their waterways immediately downstream of their gates leaves.

Since the unobstructed water passage is only maintained when the gate is fully opened, these gates are not suitable for operation at partial openings, and their application is consequently limited. Although gates of the ring-follower type are not capable of part-opening operation, they are mentioned in this article to illustrate the fact that for this type provision is made to cover the open vertical slots in the walls on each side of the water passage.

There are two ways to deal with the unavoidable vertical slots. Firstly, to cover the slots by some means, as, for example, in the ring-follower system, and secondly, to make provision for the jet to jump over the slot without touching the downstream edge. To

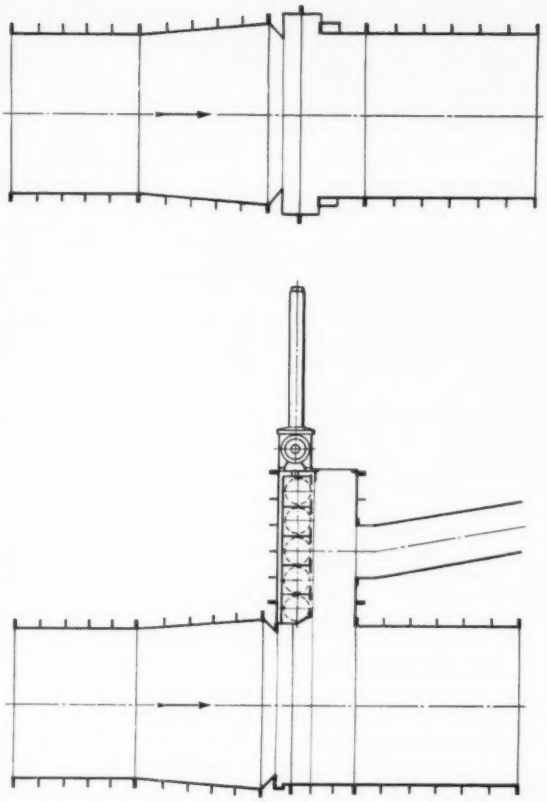

Fig. 3. Jet-flow gate

the latter group belongs the jet-flow gate, which is shown in Fig. 3.

Jet-Flow Gate: Jet-flow gates are designed to be employed as regulating gates. The gate consists of a leaf which is moved vertically on wheels by means of a mechanical or hydraulic hoist, with a leaf and surrounding housing shaped so that the water will issue from the orifice in a jet at all leaf positions.

The size and shape of the conduit are important elements in producing the desired jet characteristics. From a point approximately one diameter upstream from the face of the gate leaf the conduit is flared outward at a slope of 1 in 12 to a diameter of 120 per cent. of the jet orifice. From this point the nozzle is sloped at an angle of 45 deg. with the axial centre line of the conduit, to produce a jet which will spring clear of the wheel slots at the sides of the gate leaf and also impart a lift to the bottom of the jet and decrease the impingement of the jet on the bottom of the downstream conduit. A coefficient of 0·8 may be used to determine the magnitude of discharge at the gate orifice.

Tests reveal that two unsatisfactory conditions still exist in the latest design of the jet-flow gate. At partial openings the jet still strikes the downstream edge of the slot, and although no adverse pressure conditions have been found, wear plates are recommended to avoid trouble. This fault can also be rectified by making the conduit, downstream from the gate, horse-shoe-shaped with the flat at the bottom.

The second undesirable condition of the jet-flow

gate concerns the effect of thin fins of water originating at the points of contact of the gate with the circular orifice. In the prototype these fins or jets would be about 1 in. thick. The effect of a jet of this size striking the sides of the gate slots under high water head is a matter of conjecture. As far as is known, if water is free of sediment no erosion should occur. From the theoretical pressure distribution of a jet striking a plate, it also follows that cavitation should not occur. It is desirable, however, to prevent fins from striking the gate slot in order to maintain full air supply, and this is a very significant feature of any gate, operated under partial opening, which requires vertical slots in the sidewalls of the conduit. When a slot-gate is fully opened, the hydraulic conditions may be satisfactory, but the moment the gate is lowered and extends into the conduit, the conditions become unfavourable, as the fins spread out horizontally at the lower edge of the skinplate into the grooves and thus seal off the air supply. In the normal groove arrangement the result is that the water jet, instead of bypassing the grooves, gets partially sucked into the grooves and turbulence occurs. This is true not only for slots where the downstream edge alone is rounded or curved, but also for jet-flow gates and for conduits where the width of the conduit downstream of the slots is considerably larger than upstream.

For example, in a diversion tunnel of a high dam a plug with two conduits, 8 ft. 9 in. × 22 ft. is provided for discharging supplies for early irrigation. In these conduits, gates which are designed for 330 ft. head are located (Fig. 4). In order to maintain smooth and clear hydraulic conditions and to avoid the danger of floating debris getting stuck in the slots, the downstream width of the conduits is increased by 3 ft. to 11 ft. 9 in. Also the ceiling downstream of the grooves is raised, thus having the effect that the downstream tunnel and conduits never flow full and the pressure behind the gate is practically always atmospheric. Model tests show that with the gate fully opened the jet jumps nicely over the grooves and touches the sidewalls at approximately 10 ft. downstream of the slots. This means that practically free discharge conditions are attained. At this gate also, where the downstream edge is hidden 18 in. behind the upstream edge of the groove, under partial gate opening, the fins of water originating at the points of contact of the lower edge of the skinplate with the upstream edges of the grooves, form some kind of horizontal curtain which seals off the air supply from the lower parts of the grooves. This phenomenon causes turbulence in the grooves.

However, if it is desired to prevent the fins from striking into the gate slot, and thus maintain full air supply, a deflector might be used. In the model, the fins were deflected to a large extent by placing two vertical plates on the gate-leaf bottom, parallel to the direction of flow. The plates are approximately flush with the upstream sidewalls of the conduit. The test indicated that the vertical height of the plates should extend at least 8 in. below the lower edge of the skinplate to be effective. This would require a special chamber in the floor, and thus, while eliminating one bad feature another is created.

The hydraulic conditions of the jet-flow gate and the gates in the conduits of the plug in the diversion tunnel suggest that these provisions to make the jet jump over the slot without touching the downstream edge of the grooves will hardly be successful. It requires a considerably greater conduit width downstream of the gate than upstream, or a nozzle as provided for the jet-flow gate, to achieve the desired effect, and even with these provisions, which make the arrangement uneconomical, the conditions under partial gate opening are not satisfactory. It is the opinion of the author that some improvements may be possible along these lines, but the task of developing a gate located within a conduit which produces satisfactory hydraulic conditions under partial gate opening, and that of developing an economical combination of gate and the upstream and downstream conduit cannot be achieved by following the above-described approach.

High-Head Radial Gates: The conventional radial gate (often called a taintor gate after the name of its inventor), consists of a skinplate formed to a segment of a cylinder (Fig. 5). The vertical elements are circular arcs, which are supported by a framework of horizontal or vertical beams and stiffeners. The beams in turn may be supported by two or more radial struts

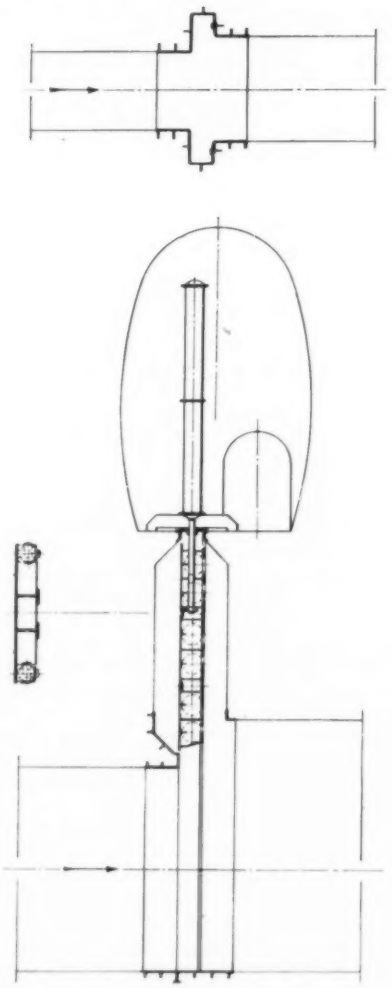

Fig. 4. Gate arrangement for 330 ft. head, showing enlarged downstream conduit

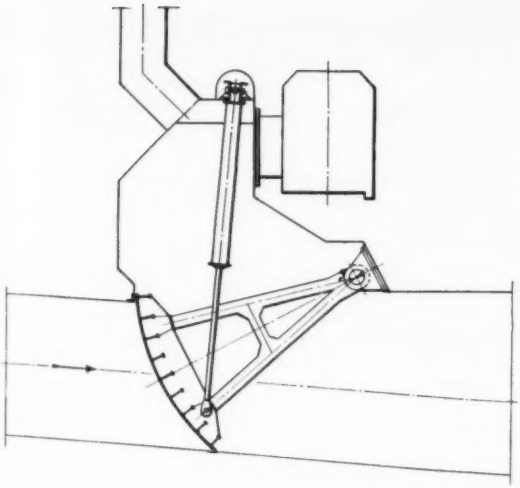

Fig. 5. High-head radial gate

converging downstream to a horizontal shaft which is anchored to the concrete face above the ceiling. The shaft carries the entire thrust of the water load. The skinplate is made concentric to the shaft so that the resultant of the water pressure creates no moment which may have to be overcome in hoisting the gate. This is the fundamental principle of a radial gate. The hoisting load consists solely of the weight of the gate, the seal friction, and the small force necessary to overcome the moment of the frictional resistance at the shaft bearings. Thus the hoisting effort for operation is less than for other types of regulating gates.

The use of radial gates in conduits appears to have several desirable aspects. The unwanted vertical slots in the sidewalls, which cannot be avoided when using a slide or fixed-wheel gate, are no longer required. A smooth bottom and sidewalls without any offsets are achieved. Hence it is possible to control the discharge and to regulate the flow to any degree of fineness without risking cavitation or erosion, and thus enabling the best possible use of the reserve water storage.

The flow at the bottom and sidewalls is not obstructed in any manner. At the ceiling, however, provision has to be made so that, under full gate opening, the jet, when parting contact with the ceiling of the conduit at the upstream edge of the recess, does not touch the bottom of the raised gate. This would seal off the air supply and cause vibration of the gate, resulting in serious damage both to the gate and to the embedded parts. The important feature of high-head radial gates developed so far is that the water is only allowed to touch the upstream face of the skinplate and no other part of the gate, including the trunnion. This gate does not, however, fulfil our basic requirement to have, under full gate opening, a smooth pipe, even one that is square in shape, without any interruptions. Furthermore, under full gate opening, ample aeration for the water jet has to be provided. This requires a larger area of the downstream portion of conduit. Not only does this make the whole conduit or outlet uneconomical, but it can also affect the safety of the surrounding structure. A mixture of water and air in a closed conduit is dangerous and unwanted. In a long conduit water and air are expected to separate. The air, which is compressed, travels along the crown of the conduit to the exit of the conduit. When the bubbles of compressed air reach the exit, they expand with bursts that sound like pistol shots and which may cause pulsation and fluttering of the outlet. This danger should specially be expected in very long conduits which discharge into the overflow spillway of the dam, and where the outflow end of the conduit bends downwards to form an elbow in order to deflect the water jet parallel to the spillway glacis.

There is no doubt that the recess in the ceiling of the conduit required for the fully raised radial gate to some extent adversely affects the otherwise very good features of this type of gate.

Even with this handicap, the author considers the radial gate to be superior to any of the types of gates commonly used for regulating flow under high head and operating within conduits.

A New Design

The author has prepared the design of a high-head gate, suitable for regulating the discharge through a conduit, with a view to securing clear hydraulic conditions. When this gate is fully opened, as shown in Fig. 6, it affords an unimpeded passageway that is essentially the equivalent of the conduit within which the gate is inserted. Expressing this in a different way, in this gate design, the open vertical slots in the wall on each side of the water passage and exposed to high-velocity flow, which are common to all conventional high-pressure gates, are eliminated. The water-passage walls afford the practically unbroken continuity so necessary for streamline flow, and the erosive action that occurs adjacent to these slots in high-pressure gates is thus avoided. This essential feature of smooth, continuous water-passage surfaces is effected by attaching two columns which fill up the vertical slots, and a horizontal plate, which is retractable, to the bottom of the gate leaf and so positioning it that when the gate is raised to the open position the interior surface of the columns and the horizontal plate are aligned with the walls and ceiling surfaces of the water-passage on all sides.

When the gate is lowered for the first few inches, the lower edge of the skinplate starts to extend into the conduit whereas the retractable horizontal plate remains in the top position flush with the ceiling. The horizontal plate is connected to the gate leaf by two vertical rods which extend through holes in the web-plates of the beams up to the top of the gate, and are there spring-mounted in such a manner that the horizontal plate remains flush with the ceiling until it is met by the web-plate of the lowest beam, where it is not exposed to the flow. During opening, when the gate is nearly fully raised, the upper ends of the rods meet the bonnet cover, which compresses the buffer springs and forces the horizontal plate to stay in a position flush with the ceiling of the conduit.

An air inlet is provided on the downstream side of the bonnet so that when the gate is in the raised position the air supply is practically sealed off. Model tests should indicate whether a series of small holes in the ceiling just downstream of the gate is required, or whether it would be advisable to arrange these holes in the retractable horizontal plate. Two symmetrically positioned inlet flanges admit air into the distributing chamber from two pipes which are later combined into one air-inlet pipe which is then carried to a screened

inlet located at an elevation above high-water level in the reservoir.

The presence of the two columns beneath the gate leaf necessitates a recess below the conduit to receive them when the gate is lowered for closing. This recess is provided by a lower bonnet which extends to the underside of the gate frames in the same manner as the bonnet above them which receives the gate leaf when it is raised to the fully opened position. The bottom of the lower bonnet is sloped towards the centre, where one drain outlet of ample area is provided to permit drainage of the interior of the gate frame and to flush out any sediment that may collect in the bottom of the bonnet. Since the gaps between the wall-plates of the columns and the wall-plates of the conduit, as well as the gaps between columns and conduit floor can be kept as small as $\frac{1}{4}$ in., and will be the same at any gate opening, only fine sediment is able to enter the bottom bonnet. In the closed position, shown in Fig. 7, the conduit is sealed upstream of the vertical slots, hence no water flows into the bottom bonnet, thus enabling it to be inspected, a manhole in the conduit floor giving the necessary access.

The columns are bolted to the bottom of the gate leaf in order to restrict the height of the inspection gallery within reasonable limits. Model tests will be necessary to determine whether the columns tend to vibrate under certain gate openings, due to differences and fluctuations of the pressure around them. It may therefore be advisable to bolt something like a traverse to the lower ends of the columns below the conduit floor. Spring-loaded slide buttons, connected to the lower ends of the columns and pushing against track and guide rails, could also be provided to eliminate possible vibration.

The method of attaching the gate stem to the leaf, the general construction of the upper bonnet cover, the hoist cylinder and the piston are similar to those usually employed in the latest types of high-pressure gate construction. The piston should be locked in the raised position or a pressure accumulator should be attached to the hoist cylinder. Thus when the oil pressure drops, the pressure pump starts building up pressure without moving the gate.

For a long conduit it may be economical to install a transition piece downstream of the gate in order to change to the more economical round section. Depending on the head, the length of the transition piece should be sufficient to maintain positive pressure against the conduit walls. The square section upstream of the gate is in some way advantageous since it enables the use of smaller and hence more economical stoplogs or emergency gates.

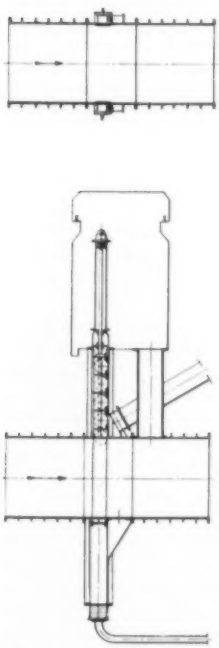

Fig. 6. Author's design of gate, fully open

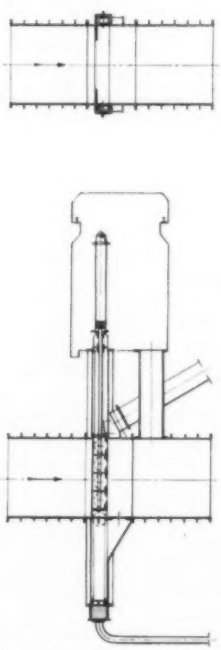

Fig. 7. Author's design of gate, fully closed

Concluding Remarks

The object of developing a high-head gate suitable for regulating the flow, and located within a conduit, is twofold:

(1) to ensure that at any gate opening the hydraulic conditions are streamlined, and

(2) when the first condition is fulfilled, to make the gate and the conduit economical.

In other words, the task is to obtain maximum discharge through the smallest possible conduit equipped with the most economical and efficient regulating device. A review of to-date achievements in this field reveals that a great deal remains to be done. No high-head gate used for regulating purposes within a conduit can claim to satisfy condition (1), which means that no gate has so far provided completely satisfactory hydraulic conditions. Without exception, all controls (when used within the conduit for regulating purposes) whether a slide gate, fixed-wheel gate or any type of ring-follower gates, as well as needle valve, tube valve or hollow jet valve, have suffered damage during operation, largely due to pitting by cavitation. Usually the valves should not be operated at certain openings since the curves of the valves cannot be shaped to follow the flow lines at any gate opening. Such a condition invariably produces cavitation. Needle, tube, and hollow-jet valves are therefore no longer used for regulating purposes within a conduit.

The outline design of the gate shown in Figs. 6 and 7 leaves a great margin for improvement. A gate based on a different principle may result in a simpler and more compact device. Nevertheless, in the author's opinion, this gate is superior to any known type of high-head gate used within a conduit for regulating purposes. It not only provides smooth hydraulic conditions at any gate opening, but it also makes possible the achievement of the highest possible discharge coefficient, which results in a smaller conduit and hence a smaller gate.

Generally, it can be said that a gate for which the hydraulic conditions are absolutely clear will work under practically any head. Gates and valves very often have given trouble when used for higher heads, which shows that the hydraulic conditions were not favourable. For smaller heads this is not significant and can be neglected, but higher heads reveal hydraulic inadequacies of a gate and its embedded parts.

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1. Calvin Victor Davis " Handbook of Applied Hydraulics."
2. Publication of the Bureau of Reclamation, United States Department of the Interior.

Downstream view of the Lawers dam

Lawers Hydro-Electric Scheme

A brief summary is given of the highest-head scheme under construction by the North of Scotland Hydro-Electric Board

THE Lawers scheme is part of the hydro-electric development of the Breadalbane district of Perthshire where in the area between Loch Earn, Loch Tay and Glen Lyon there will be eight power stations with a total capacity of 118,500 kW and an estimated average annual output of 384 million kWh. The scheme was published in 1948 and constructional work started in 1951.

The Lawers works collect the rainfall on 17½ sq. miles of catchment area comprising the Ben Lawers range of peaks along the northern shore of Loch Tay to produce annually about 80 million kWh. Water is collected at elevations from 1,720 ft. to 1,850 ft. above sea level leaving the lower and larger part of the catchment areas of these hill streams unaffected. The water from this high-level area is diverted by 13 miles of collecting aqueducts into the small Lochan na Lairige, lying 1,620 ft. above sea level on the high pass between Loch Tay and Glen Lyon. The loch is being enlarged into a reservoir by the construction at its southern end of a massive buttress-type dam, shown above, 1,250 ft. long and 130 ft. high. This will raise the surface level of the loch by 90 ft. to provide a storage of 460 million cu. ft., equivalent to 12 million kWh per annum. A low-pressure pipeline, followed by a tunnel two miles long, and then a high-pressure steel pipeline, carries the water to the Finlarig power station, 1,362 ft. below on the shore of Loch Tay. The power station is built of stone from Aberfoyle.

The Lawers scheme has some interesting features. The head of water, 1,360 ft., is the highest of any station so far built by the Board. The generator has a horizontal shaft and a capacity of 30,000 kW, the largest machine of this type installed in this country. The alternator stator weighs 50 tons and the rotor, which has a shaft about 30 ft. long, weighs 127 tons.

The alternator is driven by two twin-jet overhung Pelton turbines with a combined output of 42,000 h.p. The two turbine runners are mounted at either end of the alternator shaft, and each weighs approximately 5 tons.

The Finlarig station is fitted with control equipment to enable the generator to be started up automatically by pressing a button either in the power station itself or in a control centre in Glen Lochay. Alarm indications will be relayed back to the control centre while more serious faults will shut down the machine automatically. The electricity produced by the Finlarig station goes to a switching station in Glen Lochay, near Killin, where it is fed into the Highland Grid.

In building the scheme, four miles of public road have been reconstructed and 2¼ miles of new access road built. Some 550 men are employed on the scheme.

It was found possible to avoid interference with the rare Alpine plants for which Ben Lawers is renowned and sites of prehistoric interest in the area have been protected during the construction of the scheme.

An Experimental and Analytical Investigation of a Differential Surge-Tank Installation

By W. L. GIBSON and W. SHELSON, of the Applied Mechanics Section, Research Division, Hydro-Electric Power Commission of Ontario *

PART ONE

THE differential surge tank was developed by R. D. Johnson[1]† as an economical means of reducing and damping the flow and pressure oscillations resulting from moderate changes in the gate opening controlling the flow through a long hydraulic system.

The solution to the general proportions for the tank can be initiated from the basic mathematical treatment given in R. D. Johnson's paper; then, step-by-step arithmetic methods should be used to check the regulation characteristics of proposed designs. The water-hammer pressures in the conduits also should be determined, either by step-by-step arithmetic methods[2], or by a graphical interpretation of the arithmetic solution[3, 4], or, if sufficient simplification is permissible, by reference to Allievi's Charts[5] for water hammer in simple conduits. The large numbers of steps often necessary in practical examples can make the analysis tedious and, in the case of water hammer, the precise analysis by either arithmetical or graphical methods can become almost impracticable. Few precise data have been published from operational tests on actual surge-tank installations to support the analytical results and to assess the effects of the usual approximations.

The general problem then is:

(1) To obtain from operating tests on actual surge tank installations, experimental data to add to the store of experience.

(2) For a given surge-tank application, to assess the performance with the full precision of the recognised theoretical analyses and to assess the effects of approximations.

When the Aguasabon generating station was built in 1947-8 the opportunity arose to obtain further experimental data of surge-tank performance. During the construction period, instrumentation was installed in the hydraulic conduit system so that the tests described later in this paper could be performed when the plant was put into operation. The precise calculation by the authors of the theoretical performance was simplified when automatic high-speed digital computers became available to them several years after the plant had been designed and constructed.

Objectives of the Investigation. In order to provide specific information about the plant, and to contribute data applicable to the general problem, the objectives of this investigation were:

(1) For various rates of turbine-gate operation, to determine the water-hammer pressures together with the surge-tank and riser water level changes, caused by various selected changes in the generating station load.

(2) On the basis of the foregoing, to modify the area of the surge-tank port and the adjustment of the turbine governors if the tests indicated the need.

(3) To compare the experimental results with the corresponding analytical results, and with results calculated by approximate methods.

(4) To improve the practicable analytical approach if warranted and possible.

Fig. 1. Aguasabon generating station and surge tank

The Aguasabon Generating Station

The Aguasabon generating station consists of two

*Contributed by the Hydraulic Division for presentation at the Annual Meeting, New York, N.Y., of The American Society of Mechanical Engineers.

† Superior numerals refer to the bibliography to be published at the end of Part Two of this paper.

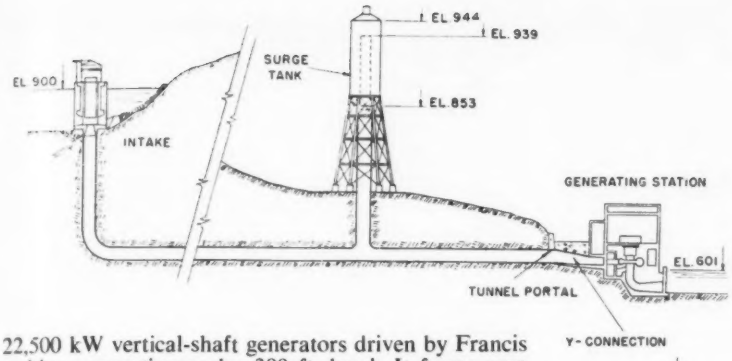

Fig. 2. Diagram of the hydraulic system at Aguasabon generating station

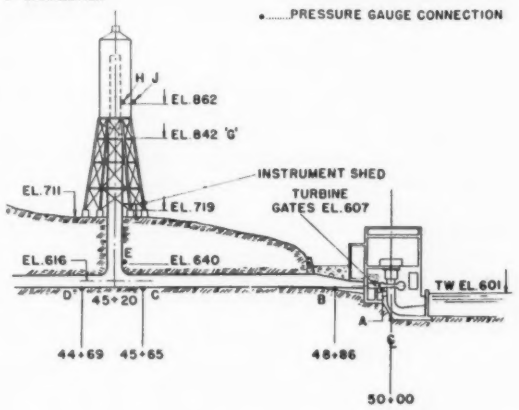

Fig. 3. Diagram showing locations of pressure gauges. (Elevations from sea level; horizontal stations from arbitrary datum with turbines at 50 + 09 and intake at 14 + 03)

22,500 kW vertical-shaft generators driven by Francis turbines operating under 300 ft. head. It forms part of a 240,000 kW system, most of the generation being from larger plants on the Nipigon river about 70 miles west of Aguasabon G.S. The plant is located on the north shore of Lake Superior about 130 miles east of Port Arthur and Fort William. A concrete gravity dam and sluiceway structure located about two miles from the mouth of the Aguasabon river retains a forebay water storage area at an elevation about 300 ft. above Lake Superior and approaching within 3,500 ft. of the shoreline at one place. The generating station is located on the shoreline and is supplied with water through a 15 ft. dia. circular concrete-lined tunnel from the storage area.

Fig. 2 shows diagrammatically a cross section on a vertical plane through the plant and its hydraulic supply system. The tunnel rises from the generating station with a slope of 1 in 200 from horizontal and turns upward in a smooth bend to join the vertical shaft from the intake structure. A differential surge tank located with its vertical axis 461 ft. from the plant is connected to the tunnel by a 15 ft. dia. vertical riser. The tank main dimensions are diameter 32 ft., inside riser diameter 13½ ft., port area 8·4 sq. ft., inside riser height above forebay level 39 ft., tank top height above forebay level 44 ft., tank bottom depth below forebay level 49 ft.

Fig. 1 shows the tank with the generating station in the background. The tunnel and surge-riser excavations are lined with concrete about 3 ft. thick. The part of the tunnel within 476 ft. of the powerhouse, and the surge riser up to ground level, are lined with steel inside the concrete. The conduit divides into two 10½ ft. dia. branches just outside the powerhouse structure to feed the two turbines. The 79 ft. length of the conduit between the tunnel portal and the powerhouse is encased in a massive concrete envelope. The surge riser above ground is a continuation of the steel lining of the shaft, and the tank and inner riser are of steel. The required port area was adjusted by blanking off part of the annulus between the vertical pipe and the inside riser. The water enters the tunnel through an intake structure housing a cylindrical-type headgate.

Test Instrumentation

The important data required from the experimental work were as follows:

(1) Dynamic water pressures at various locations in the hydraulic system.

(2) Continuous water levels in the tank and in the internal riser.

(3) Continuous values of turbine-gate opening during the operating period of each test.

(4) The initial rate of water flow in the conduit at the commencement of each test, and in some cases, the rate of flow at the end of the test.

The water levels in the tank and riser were determined from pressure measurements. The water flow at any instant during turbine-gate movement was found from a calibration of flow against turbine-gate opening, corrected for head on the turbine. Thus the instrumentation used during the tests consisted of electrically operated remote-reading fluid pressure gauges installed at the selected stations, electrically operated remote-reading turbine gate-position indicators, a multichannel oscillograph for recording the pressures and gate positions, and a differential manometer for measuring turbine discharge.

Pressure and Water-Level Measurements. The locations of the pressure stations selected for the investigation are indicated in the cross section of the part of the hydraulic system shown in Fig. 3. The pressure gauge *J* at El.862 was connected directly to the outer

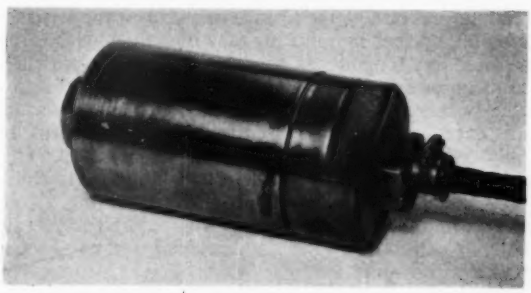

Fig. 4. Remote-reading fluid-pressure gauge

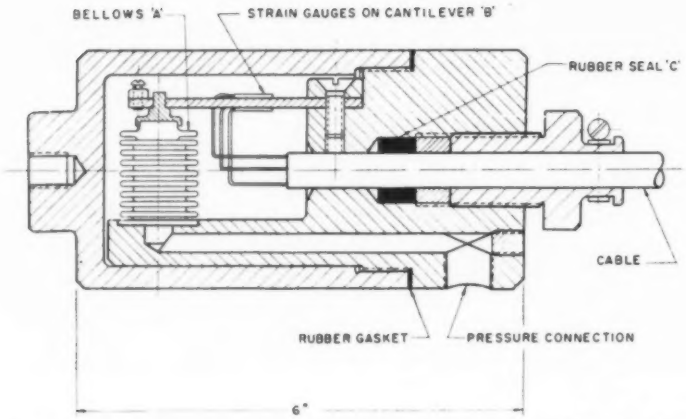

Fig. 5. Cross section of remote-reading fluid-pressure gauge

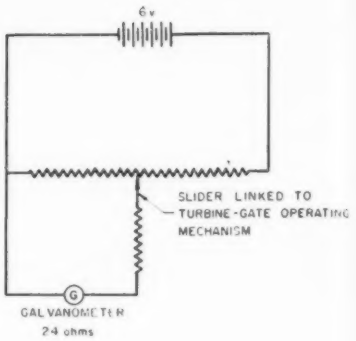

Fig. 6. Turbine-gate servomotor position-indicator circuit

tank, and the pressure gauge *H* was mounted on the outside of the tank but was connected to the inside of the inner riser by a horizontal pipe bridging the tank annulus. Bourdon-tube type pressure gauges were installed at the turbine scroll-case entries. All the other gauges were electrically operated and were made specially for the investigation; they are described later. The gauges at the buried stations were installed while the tunnel was being constructed and at the same time piezometer connections with shut-off valves were installed at the other stations. All the buried gauges were connected by electric cables to terminals and jacks on a panel-board located where the riser emerges from the rock. The board was mounted in a sheet-steel box cast into a concrete casing for protection, and a heater was included in the box to prevent water condensation. The panel casing projected into a shed erected to house the oscillograph and other test instruments.

Remote-Reading Pressure Gauges. The remote-reading pressure gauges were designed around the bonded resistance wire strain gauges that were used as sensing elements. Fig. 4 shows a photograph and Fig. 5 shows a cross section of the gauge used at the buried stations. In operation, the applied water pressure distends the metallic bellows *A* that in turn bends the cantilever *B*. Strain gauges cemented to both sides of the cantilever, near the root, respond to the surface compressive and tensile strains. The resulting electrical resistance changes cause signal voltage changes across a Wheatstone bridge in which the gauges are connected as two of the arms.

The somewhat massive proportions of the remote-reading pressure gauge result largely from the wish to use only one casing joint for easy sealing. This feature resulted in a long access passage between the pressure connection and the bellows that is usually not desirable because of the effect on frequency response. In this case, however, it was considered unimportant as only low-frequency operation was anticipated. The cable entry was sealed with a straightforward compression gland using a piece of rubber tubing, *C*, as the sealing element. The cable was secured mechanically in a slit boss on the glandnut encircled by a worm drive hose clamp.

Turbine-Gate Position Indicators. A voltage divider was used as the turbine-gate position indicator. A con-

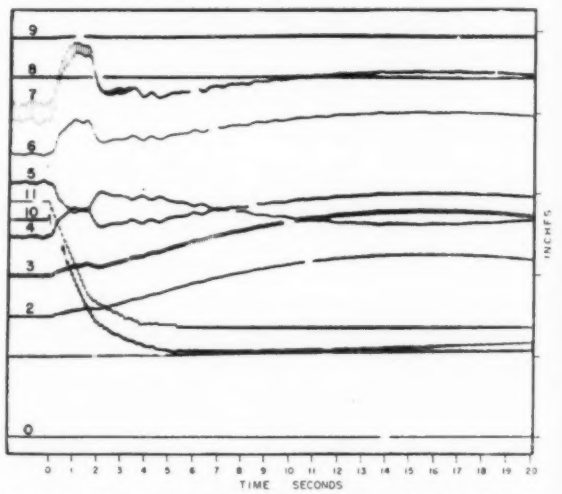

Fig. 7. Typical oscillograph record. (Load change 20,000 to 0 kW; turbine-gate movement 2·3 sec. See Figs. 11 to 15 for identification and calibration of traces)

Fig. 8. Central recording station

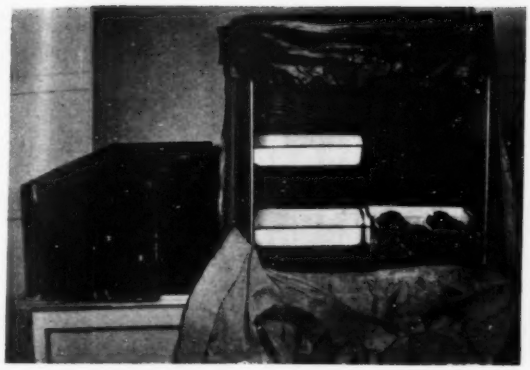

Fig. 9. Portable darkroom

Fig. 10. Darkroom in use

tact brush traversed along the length of a cylinder on which a resistance wire was wound in closely spaced insulated coils. The brush was moved along its guide bar by a mechanical linkage from the gate-operating piston rod, tapping off a voltage corresponding to its position. This voltage was connected across an oscillograph galvanometer in series with a resistance used to limit the galvanometer current. Fig. 6 shows the circuit diagram.

Water-Flow Rate. The flow versus turbine-gate-position calibration under steady load conditions was determined by the Gibson time-pressure method[6], using differential piezometers. The water flow rate at any instant during turbine-gate movement was found by determining the gate position at that instant and referring it to the calibration, adjusted for changes in head. The flows for the initial steady gate positions were determined also from previously calibrated piezometer readings in the scroll cases.

Recording Equipment. The recording equipment consisted of a commercial multichannel oscillograph equipped with electromagnetic suspended-mirror-type galvanometers. The records were made on photographic paper 7 in. wide. A typical record is shown in Fig. 7.

The pressure-gauge strain-gauge bridges were supplied with direct current from batteries, a commercial bridge-control unit being used to adjust the voltage

TABLE I—HYDRAULIC SURGE TESTS AT AGUASABON GENERATING STATION

Load Changes (Two Generators) kW	Discharge cusecs			Gate Opening Per Cent. Full Gate		Time for Gate Movement Seconds			Equivalent Full Stroke of the Gates Seconds	
	Unit 1	Unit 2	Total	Unit 1	Unit 2	Unit 1	Unit 2	Average	Unit 1	Unit 2
20000 to 0	499	465	964	45·9 to 0	41·3 to 0	3·8	3·3	3·6	8·3	7·9
20000 to 0	500	476	976	46·8 to 0	42·1 to 0	2·4	2·2	2·3	5·1	5·2
30000 to 0	687	662	1349	62·1 to 0	57·6 to 0	5·1	4·5	4·8	8·2	7·8
40000 to 0	902	897	1799	85·0 to 0	78·4 to 0	6·7	5·9	6·3	7·9	7·5
40000 to 0	904	895	1799	84·3 to 0	78·4 to 0	4·2	3·9	4·1	5·0	5·0
40000 to 0	900	889	1789	84·8 to 0	78·0 to 0	3·5	3·2	3·4	4·2	4·2
46300 to 0	1035	1075	2110	100·0 to 0	99·8 to 0	8·0	7·5	7·8	8·0	7·5
46300 to 0	1035	1067	2102	100·0 to 0	99·8 to 0	5·2	5·0	5·1	5·2	5·0
46300 to 0	1039	1078	2117	100·0 to 0	100·0 to 0	4·3	4·3	4·3	4·3	4·3
0 to 20000	509	502	1011	0 to 47·1	0 to 44·2	5·1	5·6	5·4	10·7	12·7
20000 to 40000	488 to 897	474 to 902	962 to 1799	opened 38·9	opened 37·6	4·4	5·3	4·9	11·3	14·0
20000 to 40000	497 to 909	477 to 879	974 to 1788	opened 38·6	opened 35·0	2·3	2·4	2·4	5·9	6·8
20000 to 40000 to 0*	489 to 874	467 to 865	956 to 1739	45·0 to 84·0 to 0	41·6 to 78·0 to 0	4·6 & 6·6	5·0 & 6·0	4·8 & 6·3	11·7 & 7·8	13·6 & 7·7
20000 to 40000 to 0†	498 to 870	477 to 860	975 to 1730	46·4 to 84·1 to 0	42·6 to 77·7 to 0	4·3 & 6·6	4·8 & 5·6	4·6 & 6·1	11·3 & 7·8	13·7 & 7·2

* Forty seconds delay between start of gate opening and closure.
† Thirty seconds delay between start of gate opening and closure.

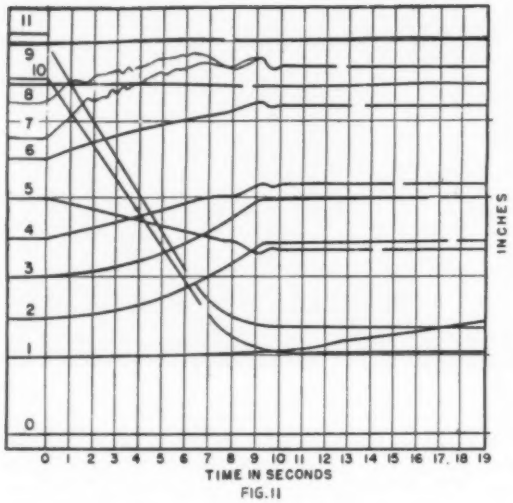

FIG.11

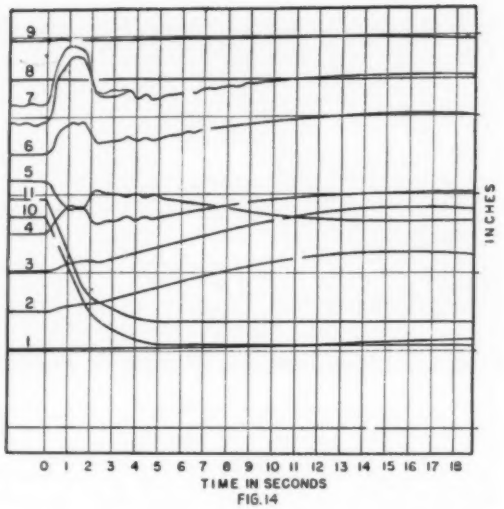

FIG.14

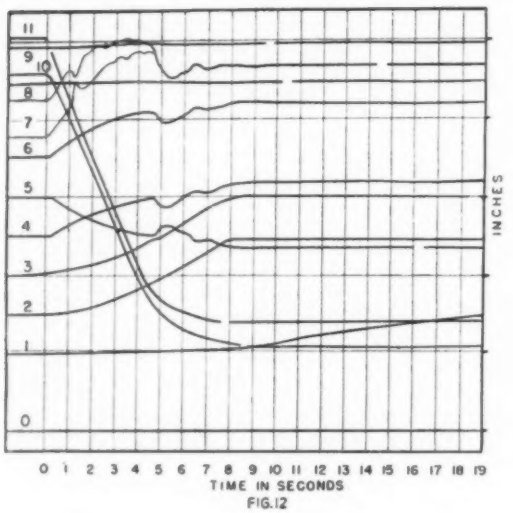

FIG.12

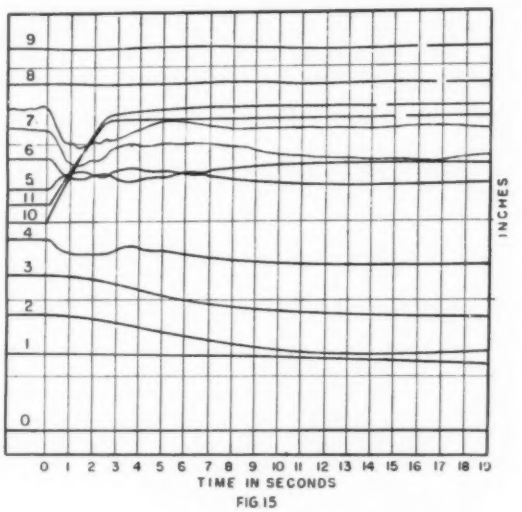

FIG.15

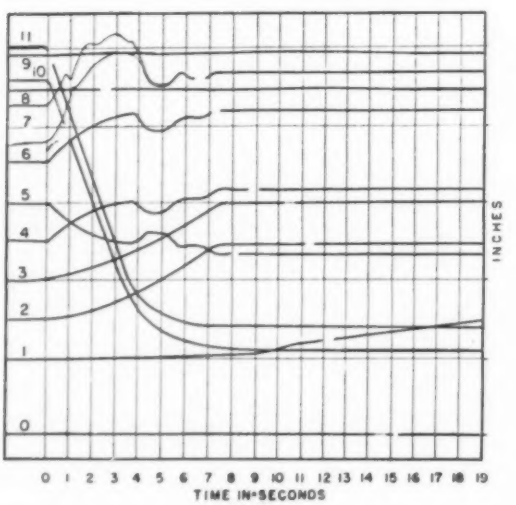

FIG.13

Figs. 11-15. Tracings of oscillograph records

Fig. 11. Load change, 46,300 to 0 kW; gate time, 7·8 sec.
Fig. 12. Load change, 46,300 to 0 kW; gate time, 5·1 sec.
Fig. 13. Load change, 46,300 to 0 kW; gate time, 4·3 sec.
Fig. 14. Load change, 20,000 to 0 kW; gate time, 2·4 sec.; equivalent full stroke, 5·2 sec.
Fig. 15. Load change, 20,000 to 40,000 kW; gate time, 2·4 sec.; equivalent full stroke, 6·4 sec.

KEY TO TRACES

0	Datum line	
1	Pressure in outer tank (EL 862)	21·8 lb. per sq. in.
2	Pressure in riser (EL 862) ...	21·9 " " " "
3	Pressure in riser (EL 842) ...	21·0 " " " "
4	Pressure in riser (EL 640) ...	31·1 " " " "
5	Pressure in conduit (44+69) ...	30·1 " " " "
6	Pressure in penstock (45+65)	32·8 " " " "
7	Pressure in penstock (48+86)	31·4 " " " "
8	Steel strain in penstock (45+49)	183 microin./in./in.
9	Steel strain in penstock (46+05)	211 microin./in./in.
10	Gate position	Unit No. 1
11	Gate position	Unit No. 2

NOTE: The wide band formed by Trace 7 occurred because the pressure gauge natural frequency almost coincided with the 81 c.p.s. frequency of a turbine vibration induced by the movement of the runner blades past the guides vanes.

TABLE II—MAXIMUM PRESSURE CHANGES DURING TESTS

Load Changes (Two Generators)	Time for Gate Movement. Average of the two Turbines	Outer Tank EL. 862 I*	Inner Riser EL. 862 H	Main Riser EL. 842 G	Main Riser EL. 640 E	Conduit STN. 44+69 D	Conduit STN. 45+65 C	Conduit STN. 48+86 B	Scroll Case Entry STN. 49+50 A
kW	sec.	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.
20000 to 0	3·6	5	17	17	17	16½	17	—	17½
20000 to 0	2·3	5¼	16¾	16½	17¼	16	17	25	29¾
30000 to 0	4·8	7¾	19	19	19	18	19¼	—	21½
40000 to 0	6·3	12½	20½	20½	21	19¼	20½	20	26
40000 to 0	4·1	12½	20¾	20½	21	19½	21¼	27¼	35
40000 to 0	3·4	12½	20¾	20½	21	19¾	21½	31	40
46300 to 0	7·8	16	21½	21½	22½	21¾	24	24½	31
46300 to 0	5·1	16¼	21½	21¾	21½	20¾	23	27½	38
46300 to 0	4·3	16¼	21½	21½	21¼	21	23	33	44
0 to 20000	5·4	−5¾	−16½	−16½	−15	−14½	−15½	−13½	−16
20000 to 40000	4·9	−4½	−12¾	−12½	−11¼	−10½	−12½	—	−13¼
20000 to 40000	2·4	−4½	−11¾	−12	−11½	−10¾	−11½	−19¾	−20½
20000 to 40000 to 0	4·3 & 6·3	−4¾ & +10½	−12 & +18½	−12¾ & +18¾	−11¼ & +18¾	−10¾ & +17¾	−12 & +19¼	−10¾ & +19¾	—
20000 to 40000 to 0	4·6 & 6·1	−4½ & +9½	−12 & +18½	−12 & +18½	−10½ & +18½	−10¼ & +17¾	−11¾ & +19	−10¾ & +17½	—

* The letters refer to the pressure station identification used in Fig. 3.
The values in Column D are believed to be slightly less accurate than the remaining figures which are estimated to be correct within 5 per cent.

and to balance the bridges. The bridge output signals were fed directly to the galvanometers without amplification. The pressure-gauge calibrations were about 20 to 30 lb. per sq. in. of oscillograph-trace deflection and the traces could be measured to about 0·01 in. The precise calibration figures are listed in Figs. 11 to 15. The galvanometer frequency response was flat up to 100 cycles per second.

The gate-position indicators were connected to the galvanometers through resistance boxes that were adjusted to give trace deflections of about 3·3 in. for full gate travel.

Fig. 8 shows the recording station with the instrumentation installed. The two bridge-amplifiers on the right were used to amplify the signals from resistance-wire strain gauges mounted on the outside surface of the steel lining of the conduit.

Surge Tests

The surge tests were carried out with all the generating plants on the system alerted. At the beginning of each test the Aguasabon station turbine governors were adjusted to give approximately the desired rate of gate operation and the plant was operated at the selected initial steady-state power output. The water-flow rate was measured and the selected load-change operation was initiated. During the tests the units remained on the line at all times. Load rejections were made by operating the turbine governors manually, and load was picked up by operating the governors manually up to the preset load-limit stop. Fourteen effective test operations were carried out as listed in Table I.

During the progress of the tests, the photographic records were processed immediately after each test operation so that the water pressures and surge-tank water levels could be determined before proceeding to the next scheduled operation. A small portable "darkroom" of rubberised waterproof twill was used.

Fig. 9 shows a photograph of a darkroom packed for carrying and of the internal arrangement when erected, and Fig. 10 shows the equipment in use. The required approximate measurements were made on the record after it had been in the fixing bath a few minutes, then the fixing process was completed while the next test operation was in progress. The most important results of each test were available for discussion in less than 10 min. This factor was extremely valuable as it avoided loss of time between tests and permitted each following test to be approached with confidence.

Experimental Results

The maximum and minimum pressures measured at the various places in the hydraulic system during each test, are listed in Table II. Figs. 11 to 15, inclusive, show tracings of the oscillograph records for the following tests:

Plant output (kW)	Turbine gate time(sec.)
1) 46,300 kW to 0	7·8
2) 46,300 kW to 0	5·1
3) 46,300 kW to 0	4·3
4) 20,000 kW to 0	2·3 (equivalent full stroke 5·2 sec.).
5) 20,000 kW to 40,000 kW	2·4 (equivalent full stroke 6·4 sec.)

The foregoing turbine gate times are equivalent times for linear closure of the gates without including the cushioning part of the stroke. The average for the two turbines was used.

These representative test conditions were selected for comparisons between results obtained experimentally and results calculated analytically. Later in the report the comparisons are presented in graphical form.

(To be continued)

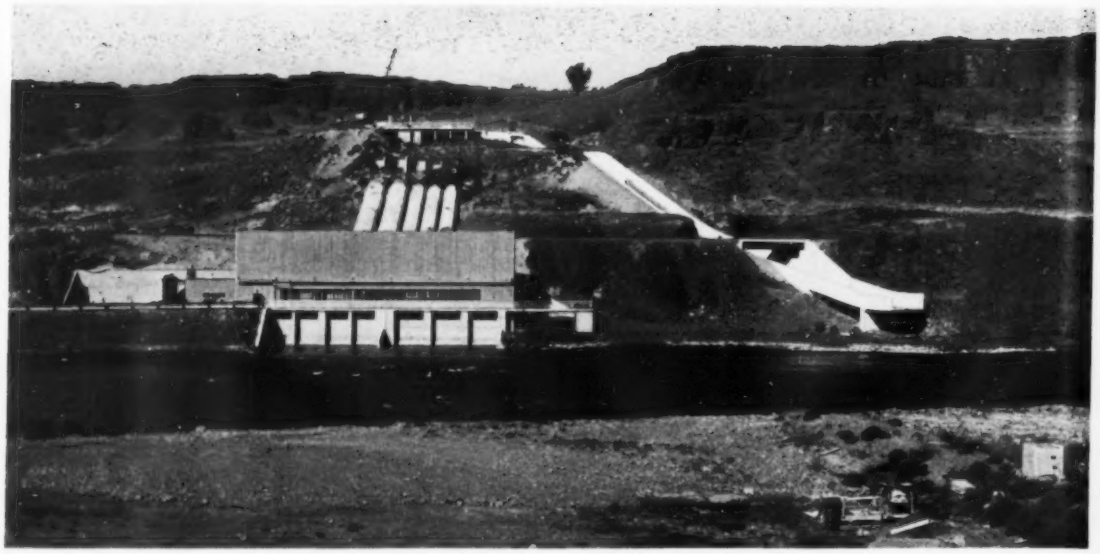

Fig. 1. Chandler power and pumping plant seen from the south side of Yakima River

The Chandler Power and Pumping Plant

Construction is essentially completed on the Chandler power and pumping plant, a principal feature of the Bureau of Reclamation's Kennewick Division of the Yakima project in the State of Washington. Power from the first of the plant's two 6,000 kW generating units was made available for commercial use on January 9, 1956, and the second unit was put into operation on January 12

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THIS article describes the Chandler installation, its function in the operation of the Kennewick Division, and its contribution to the overall development of the Yakima project. From an engineering standpoint, the plant is of particular interest because of the dual function of power and pumping incorporated in the one installation and the diversity of hydraulic and structural features required in its operation.

Yakima Project

The Yakima project is one of the most productive of the Bureau of Reclamation's water and land resource developments in the 17 western states of the United States. Yakima County, in which lie two-thirds of the irrigated lands of the project, rates first among all the counties in the United States in the production of apples, pears, and hops. The county also ranks high in the production of cherries, plums, and peaches, and other fruits. Appropriately, the area has been called the "fruit bowl of the nation." Agriculture of the project has provided the foundation for thriving industrial and business enterprises and prosperous cities and rural communities in the Yakima Valley.

The project comprises six divisions: Storage, Kittitas, Tieton, Sunnyside, Roza, and Kennewick, which irrigate lands adjacent to the Yakima River in the 176 miles between Easton and Kennewick, Washington. When the Kennewick Division is fully constructed, the Yakima project will embrace about 480,000 acres of irrigated land.

The Yakima project as a whole was authorised by the Secretary of the Interior in December 1905. First construction was undertaken in March of 1906, and water was first made available on the Sunnyside Division in April 1907. The project now includes six storage reservoirs, having a total capacity of 1,063,800 acre-feet, five diversion dams, and 25 pumping plants.

Kennewick Division

The Kennewick Division is a multiple-purpose development which will provide irrigation, power, and fish and wildlife benefits. Development of the Division was authorised by the Congress of the United States on June 12, 1948. Funds for starting the construction were made available by the Congress in 1952.

The Division consists of a narrow strip of land 32 miles long, from ¼ to 4 miles wide, and is oriented in a northwest-southeast direction. It is located at the junction of the Snake and Yakima Rivers with the Columbia River. The lands of the Division occupy stream terraces in the west portion and an old channel of the Yakima River in the central portion and higher bench lands adjoining presently irrigated land in the eastern portion. All of the Division lands are in Benton County in south-central Washington.

The Kennewick Division will supply water from the Yakima River to about 4,600 acres of presently irrigated land and to 14,500 irrigable acres of land not yet irrigated. Nearly all of the Division lands are within the boundaries of the Kennewick Irrigation District, which is acting as the contracting organisation for repayment of construction costs. Irrigation repayment and revenues from surplus saleable power will repay all construction costs chargeable to irrigation.

The Division lands have a long growing season, good-quality soils adapted to a wide variety of crops, and a water supply which is adequate without the construction of storage works. The arable soils of the area are chiefly silt loam and sandy loam generally well suited to cultivation under irrigation. The topography varies from gentle slopes on the broad terrace tops and valley floor to more sloping or irregular areas and relatively steep slopes along the draws which occur at frequent intervals.

Construction of the Division's irrigation, power, and other facilities will create about 250 full-time farms and will provide an economic basis of livelihood for many more persons engaged in a wide variety of trades, transportation, and manufacturing activities.

Prior to World War II, the area encompassed by the towns of Kennewick, Pasco, and Richland, in which the Kennewick Division is located, was predominantly a rural community supported largely by irrigated agriculture. During World War II, the Government acquired about 400,000 acres of land in the triangle formed by the Yakima and Columbia Rivers for the Hanford Engineering Works of the Atomic Energy Commission. Approximately 7,000 acres of this land were irrigated, and their withdrawal resulted in a material reduction in the food production capacity of the area. The backwater from McNary dam recently constructed by the Corps of Engineers and located on the Columbia River 29 miles downstream from Kennewick, inundates another 1,500 acres of presently irrigated crop lands southeast of the town of Kennewick. In addition, over 2,000 acres

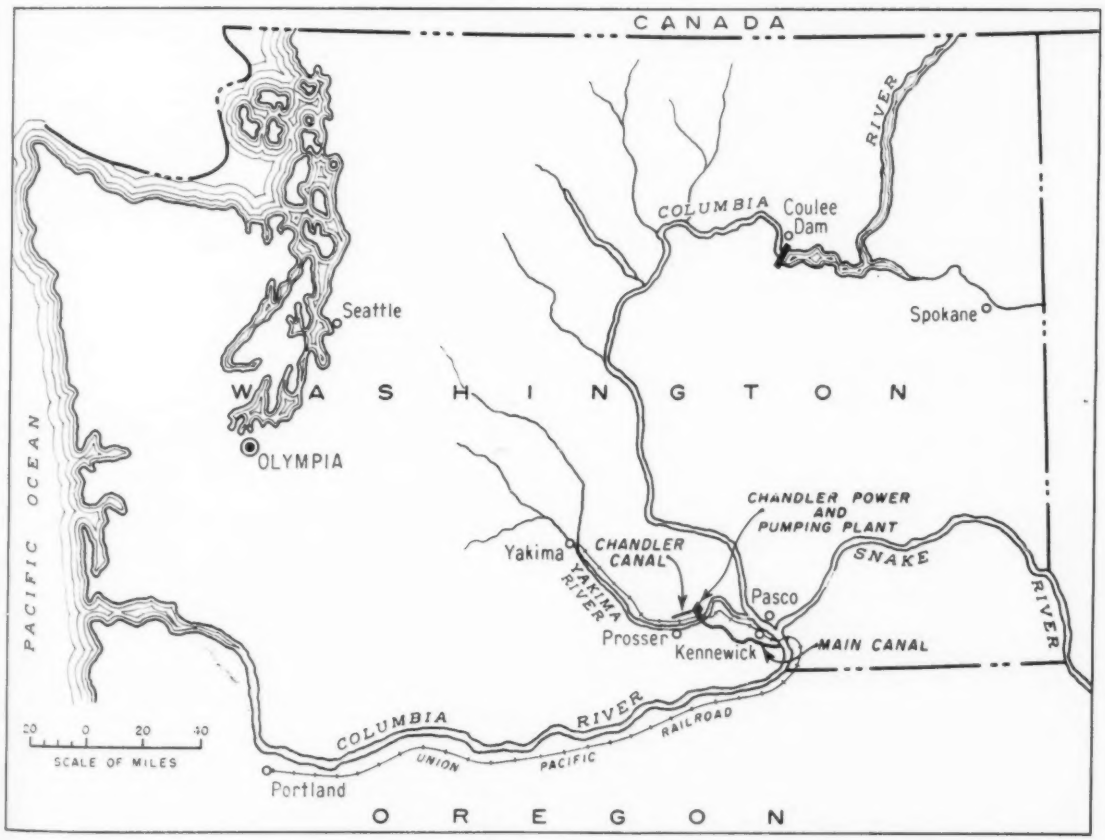

Fig. 2. Map showing the location of the Chandler power and pumping plant

have been subdivided and converted into residential lots or acreages to house the increased population, resulting in a greater reduction in the crop lands of the area. Thus, development of the Division will replace land removed from agricultural production by the construction of the Hanford Engineering Works, McNary dam, and residential development.

The water supply for the Kennewick Division is obtained from the Yakima River by a diversion dam near the town of Prosser. This dam, acquired by the Bureau of Reclamation from the Kennewick Irrigation District in March 1931, is a low, gravity-type concrete overflow weir. The diverted water is conveyed in the 1,500-cusecs capacity Chandler canal along the north side of the Yakima River to the Chandler power and pumping plant located adjacent to the river about 10 miles downstream.

Briefly, the plan of operation of the plant is this: irrigation water is lifted 101·5 ft. by three direct-connected turbine-driven pumps and discharged through a discharge line extending across the Yakima River to the Main Canal, the division's major irrigation artery on the south side of the river. (Two of the three pumping units have been installed; the third unit of the same capacity will be installed at a later date when 61,000 acres of lands now in deferred status are irrigated.)

The Chandler power and pumping plant is designed to provide the necessary flexibility in effectively utilising the available water supply under the limits of canal capacity, and of water in excess of irrigation requirements. It will be operated at as near full capacity throughout the year as available flows will allow.

During the winter (November to the end of March) sufficient water is expected to be available to operate the plant at full capacity to produce saleable power. During the irrigation season power output will be restricted to the surplus water available after irrigation, irrigation pumping, and migratory fish needs are satisfied. Power produced at the plant will be marketed by the Bonneville Power Administration, an agency of the United States Department of the Interior having an extensive power transmission system in the Pacific Northwest.

Power and Pumping Plant Structure

For economy of construction and efficiency of plant operation, the power and pumping units at the Chandler installation were combined into one structure, utilising a single forebay, headworks, and tailrace for both the power and pumping features. The combined building has a reinforced-concrete substructure and intermediate structure. It has an overall length of 170 ft. 9 in. The power-plant area of the structure is 77 ft. long by 48 ft. 6 in. wide and the pumping plant area is 63 ft. 9 in. long by 37 ft. wide. The control room adjacent to the power-plant area is 30 ft. long by 24 ft. 6 in. wide. The superstructure of the building is of structural-steel framing and has insulated metal wall panels.

An electric cab-operated indoor overhead travelling-type crane, having a span of 29 ft. 2 in., operates on a runway which extends the length of the power and pumping plant. The crane, used for installing and maintaining the turbines, generators, and pumps, is equipped with a 30 ton capacity hoist powered by a 40 h.p. motor.

Forebay and Headworks

Water discharging from the Chandler canal enters the forebay structure, which has five major parts: the terminal section of the Chandler canal; the forebay proper; a wasteway, comprising a spillway chute, an ice sluice, an automatic siphon spillway, and an outfall section; a 48 in. diameter sluice pipe; and a headworks structure. These five parts will now be briefly described.

The terminal section of the Chandler canal is identical in design to the upstream canal cross section, except that the canal lining for this terminal section and for a distance of 7,000 ft. upstream is a foot higher to accommodate wave surges that could be caused by possible power outage in the power plant and sudden closure of the turbine wicket gates. Thus, the 7,000 ft. reach of the canal, terminating at the forebay, has a freeboard of 2½ ft. in contrast to the 1½ ft. freeboard for the remaining upstream reach of the canal. At its junction with the forebay structure, the canal is crossed by a reinforced-concrete highway bridge (for the Inland Empire Highway), which was built under the contract for the construction of the Chandler plant and its appurtenant works.

The forebay proper is an open structure 275 ft. long, having a full width of 80 ft., except at its downstream end where it decreases in width to 60 ft. at the headworks. The forebay is flanked by two 14-ft. high reinforced-concrete cantilever retaining walls and has a reinforced-concrete floor slab 6 in. in thickness.

The design proportions of the forebay structure were dictated by the requirement that approximately half an acre of water surface would be needed for partially damping a possible bore wave caused by sudden closure of the turbine wicket gates in the power plant. Another design requirement which led to the building of the 275-ft. long structure was the necessity that water entering the forebay from the canal be diffused before reaching the headworks.

Flanking the downstream end of the forebay structure at an angle of about 30 deg. is the wasteway chute which is designed to discharge the full capacity of 1,500 cusecs of water entering the forebay in the event of power outage in the power plant and to carry away ice accumulations that may form during the winter months. The reinforced-concrete wasteway chute is about 370 ft. long, has a clear width of 20 ft., and is built up of a 9 in. floor slab and training walls 7 ft. in height. It slopes downward from the forebay at an average angle of about 17 deg. and terminates in a level outfall section, through which the water and ice accumulations discharge directly into the Yakima River below.

Design and construction of the wasteway chute were complicated by the location of the track of the Union Pacific Railroad which runs parallel to the Yakima River immediately upstream of the power and pumping plant and which intersects the wasteway chute at a skew angle of about 57 deg. Accordingly, a structural-steel railroad bridge about 33 ft. long, was built to pass over the chute, the concrete bridge abutments serving as training walls for the chute. About 15 ft. downstream of the bridge, a heavily reinforced concrete pier, 21 ft. high, was constructed at the edge of the river to support the outfall section of the chute. The outfall section cantilevers about 20 ft. beyond the pier at a height of 17 ft. above the normal water surface of the river.

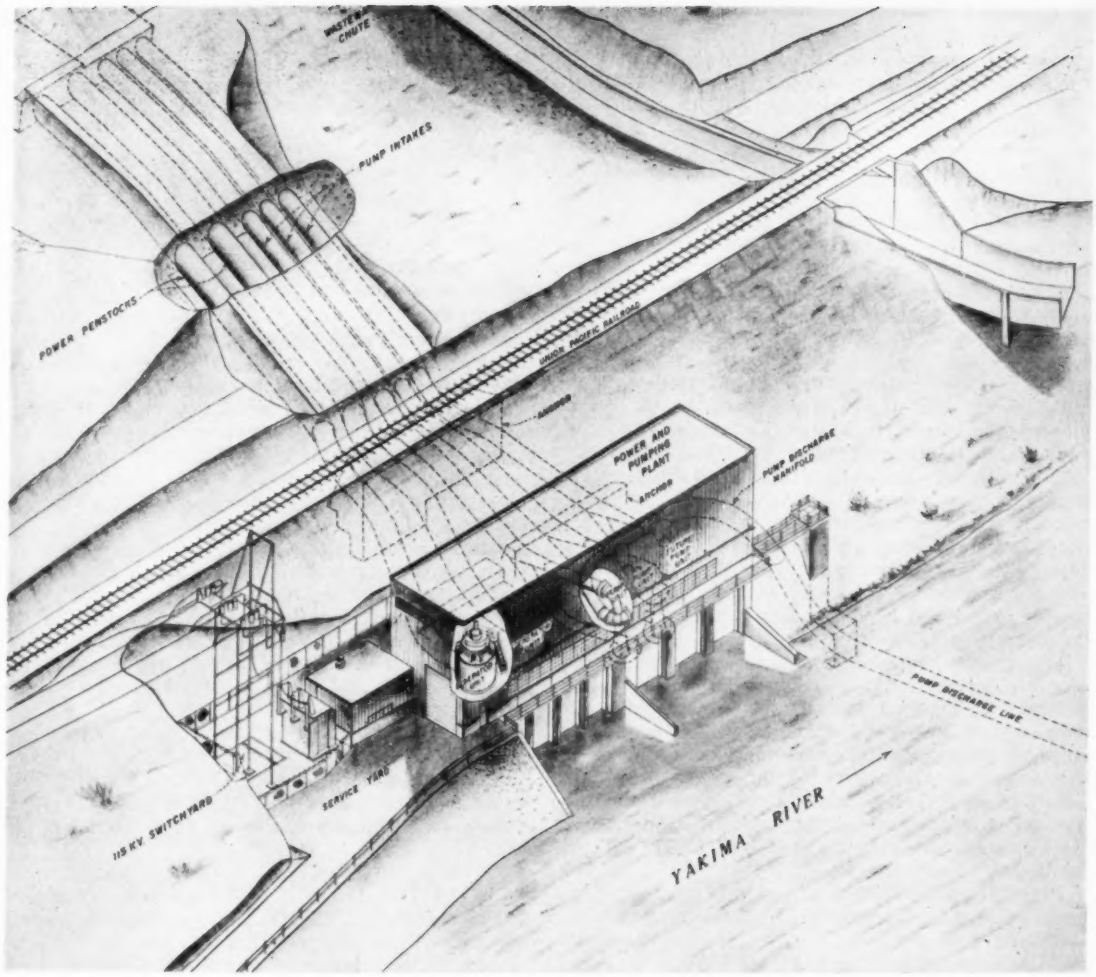

Fig. 3. Ghost view of the Chandler power and pumping plant

A battery of four automatic siphon spillways, capable of passing the full 1,500 cusecs of the canal capacity, comprises the initial section of the wasteway. These are of reinforced-concrete construction, and each spillway has a crest width of 6 ft., separated by a 12 in. wall. The height of the siphon throat for each spillway is 2 ft. 6 in.

Extending transversely across the forebay structure at an angle of about 30 deg. is an ice boom supported on a steel hawser. The hawser is anchored at the upstream end by a concrete anchor placed beyond the right forebay training wall, and at the downstream end by an anchor built into the dividing wall between the adjustable-crest ice gate and the automatic siphon spillways. The ice boom diverts floating ice cakes and debris over the adjustable-crest ice gate. Ice and debris then pass through the ice sluice built adjacent to the siphon spillways and are diverted into the wasteway chute for discharge into the river.

The adjustable-crest ice sluice gate is 20 ft. wide and 4 ft. high and is hinged at the bottom to the sill of the ice sluice. A standard motor-operated radial-gate hoist, having a special drum pedestal, is used to operate the gate. Fabricated from structural-steel members, the gate is completely welded, except the downstream side and ends which are lagged with timber to minimise icing on the downstream or weather side of the gate. Rubber seals are provided at the gate hinges and sides. The side seals bear against steel wall plates which are heated (as described below) to keep the seals free of ice.

An important consideration in the design and operation of the wasteway was the prevention of ice which could adhere to critical surfaces of the wasteway appurtenances and seriously interfere with their operation. Electric power, utilised for heating, is considered to be the most advantageous method of protecting such surfaces against freezing. However, as electrical-heating designs previously used present difficulties in operation and maintenance, an induction-heating method—novel to Bureau of Reclamation engineering practice—was developed to enhance the operability of the wasteway. The method involved the use of an embedded network, or grid, of steel conduit containing an insulated electrical cable. The cable ends are connected to the low-voltage winding of a step-down transformer.

In operation, when an alternating current of

approximately 125A flows in the circuit, the alternating magnetic flux in the conduit causes heat to be generated in the walls of the conduit. The effective amount of heat developed is regulated in accordance with existing weather conditions by using a timing control which energises the heating circuit during a predetermined proportion of the time. The formation of ice which could render the structure inoperable is thus prevented.

This simple and intrinsically reliable system of induction heating, tested in the Bureau's engineering laboratories in Denver, was installed to prevent the formation of ice on the sill plate of the ice sluice gate, the siphon spillways' entrance, the ice sluice channel floor, and the crests of the siphon spillways. For operating purposes, three separate electric heating circuits were provided. One circuit heats the entrance to the siphon spillways and the steel wall plates of the ice sluice channel. The second circuit heats the ice sluice channel floor, and the third the crests of the siphon spillways.

In addition to the three circuits installed for induction heating, a fourth circuit was installed utilising radiant heaters mounted above the siphon breaker slots. Radiant heating was selected for these surfaces because the slots are constructed of thin metal plates and cover a small area, and the use of induction heating would have been impracticable, particularly as the plates dissipate heat rapidly.

The radiant heaters are rated at 1,500 W and are arranged for operation on a 240 V circuit. Since less heat will be required during mild weather, when air temperatures are only slightly below freezing, and to conserve power, a time cycle was incorporated into the system, the heating being turned on and off in predetermined time periods. Thus, even if a small amount of icing occurs during the "off" period, the ice will break loose during the "on" period without interfering with operation.

Extending transversely across the forebay at an angle of about 60 deg. is a depressed channel, 8 ft. wide and 2 ft. deep, built in the forebay floor immediately upstream of the headworks, to act as a sand trap. When the forebay is unwatered, sand is washed from the trap by high-pressure hoses into a 48 in. precast concrete sluice pipe which connects to the wasteway chute about 60 ft. downstream from the siphon spillways. Flow into the sluice pipe is controlled by a 48 in. cast-iron sluice gate installed on the left end of the headworks. The gate is raised and lowered manually by means of a crank on a pedestal lift at the top of the headworks structure.

The headworks for the power and pumping plant is a 60 ft. wide reinforced-concrete structure which serves as the main entrance to the plant's two power penstocks and three pump intake pipes. Built as an integral rectangular framework, the headworks structure has five blockout openings for the intakes and penstocks. Steel trashracks are provided at the face of each opening to prevent debris entering the water passages.

A 10 ft. by 10·6 ft. fixed-wheel gate is installed near the entrance of each of the two turbine penstocks, and a 7·25 ft. by 7·39 ft. fixed-wheel gate is installed near the entrance of each of the three pump intakes. The gates are used for emergency closure in the event of damage to the penstocks, turbines, or pumps, and for unwatering the penstocks and intakes to permit inspection and maintenance. They are flat, structural-steel members of welded construction and have two flanged wheels on each side. The wheels support the water load on the gate and bear against steel tracks which are fastened to bases that are embedded in concrete on the downstream face of the gate slots. The gates operate in vertical slots extending from the top of the headworks structure to the bottoms of the penstocks and pump intakes, respectively.

Each of the gates is operated by a hydraulic hoist which is direct-connected to a gate stem and is supported on top of the gate chamber. The hoist is single acting, pressure being applied only to the bottom of the pistons, closure being effected by gravity.

Penstocks and Pump Intake Pipes

From the headworks, water is diverted through two power penstocks and three pump intake pipes. (Only two of the pump intake pipes are now in use; the third will be placed in use when the third pump is installed at a later date.) Each of the two power penstocks and the three intake pipes begins at a 20 ft. long square-to-round reinforced-concrete transition section, continues through a reinforced-concrete barrel section, and terminates in a steel pipe section leading to the power turbines and pump turbines. The concrete sections for the two power penstocks are each approximately 162 ft. long and have a wall thickness of 12 in. and an inside diameter of 120 in. The concrete sections for the three pump intake pipes are the same length as the power penstocks and have a wall thickness of 9 in. and an inside diameter of 87 in.

All five concrete conduits were placed in an excavated section on compacted backfill of selected material under the entire length of each barrel. The concrete conduits were built in sections, 9 in. rubber waterstops being inserted around the periphery at the contraction joints.

Provision has been made in each conduit for the temporary installation of brine-injection equipment and two electrodes spaced approximately 80 ft. apart to facilitate the determination of flow by the salt-velocity method. Manhole structures, 5 ft. 4 in. square, having 20 in. manholes, were built about 60 ft. downstream from the headworks to provide access to the conduits when the gates in the headworks are closed.

The two steel penstocks leading from the concrete conduits to the power turbines are approximately 94 ft. long and have inside diameters of 120 in. which are reduced to 96 in. at the downstream end to match the turbine inlets. The wall thickness of the penstocks, except the make-up sections, is $\frac{3}{8}$ in. The steel intake pipes for the pump turbines have an overall length of about 117 ft., an inside diameter of 87 in., and a plate thickness of $\frac{5}{16}$ in.

About 66 ft. downstream from their connections to the concrete conduits, the three steel intake pipes each have a bifurcating branch, one leg terminating in a 54 in. inside-diameter pipe connecting to the turbine of the pump-turbine unit, and the other to the pump and terminating in a section having an inside diameter of 48 in. The branches of the third intake pipe are closed with dished heads, as they will not be used until the third pump is installed.

Water from the pumps is discharged through a steel discharge manifold, which is about 68 ft. long, extends in a horizontal position between the legs of the branches of the three pump intake pipes, and is built up of sections varying in wall thickness from $\frac{1}{4}$ in. to

$\frac{7}{16}$ in. The inside diameter of each of the manifold's three branches connecting to the pumps is 42 in. and the diameter of the discharge pipe is 99 in.

A steel-reinforced mortar coating was applied to all exterior surfaces of the steel pipes, except those surfaces embedded in concrete or exposed to the atmosphere.

The pipe bends of the penstocks and pump intake pipes under the Union Pacific Railroad crossing are embedded in concrete anchors which also serve as supports for the railroad tracks. Anchorage for the lower bends of the penstocks, the branches of the intake pipes, and the discharge-pipe manifold is provided adjacent to the power and pumping plant.

Turbines

Two 8,500 h.p. turbines are provided for the generating units in the power-plant area. They are of the vertical-shaft Francis type, having welded plate-steel spiral cases and elbow-type draft tubes. Radial joints in the casing were field-welded. The 8,500 h.p. capacity is required at full gate opening when the turbines are operating at 240 r.p.m. under an effective head of 118 ft. At this head, and at an output of about 7,300 h.p., the warranted efficiency of the turbines is 90 per cent. At heads above 118 ft., the turbine output will be limited to the generator capacity by restricting the turbine gate openings as required.

The turbines are designed to operate satisfactorily at net heads between 106 and 122 ft. At rated head and full gate opening, the predicted discharge from one turbine is 735 cusecs. Turbine casing design pressure is 70 lb. per sq. in.

The governors for regulating the speed of the turbines are of the oil-pressure vertical gate-shaft type, having electrically driven speed-responsive elements. The governors are designed to operate the turbine gates through a complete closing or opening stroke in 3 sec. at an initial oil pressure of 250 lb. per sq. in. and a head on the turbine, including water hammer, of 156 ft. Means are provided on the governors to limit the rate of movement of the turbine gates for a full closing or opening stroke to any rate between 3 and 12 sec.

Situated in a stilling-well house to the right of the right retaining wall of the forebay structure, and near the headworks structure, is a forebay float control which was furnished by the governor manufacturer. The float automatically controls the water level in the forebay by varying the turbine gate opening. This is accomplished by a pair of selsyn motors which link water level in the forebay to load limit in the governors. The load the unit can assume thus varies to correspond to the amount of water available. The float control may be overridden by manual control at the governors.

For the pumping installation, there are at present two vertical-shaft Francis-type turbines having cast-iron spiral cases with conical-type plate-steel draft tubes. Each turbine has a rated capacity of 2,600 h.p. at full gate opening when it is operating at 450 r.p.m. under a net head of 118 ft. At this head, and at an

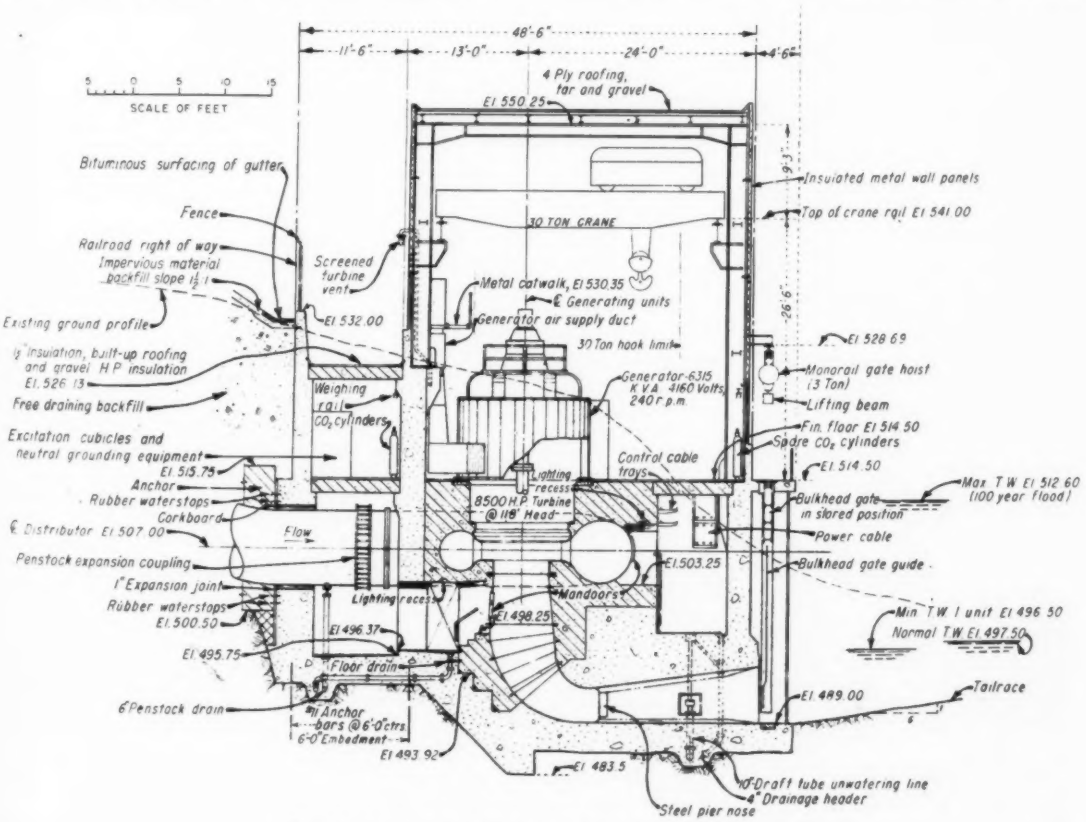

Fig. 4. Section through one of the generating units

approximate output of 2,400 h.p., the warranted efficiency is 88·5 per cent. The turbines may operate at part-gate for extended periods. They may also operate in the reverse direction of rotation because of water in the pump discharge line returning through the pumps. Space is provided in the plant for a third turbine to be added eventually of the same capacity.

The turbines are required to operate satisfactorily at net heads between 103 ft. and 122 ft. At the rated head and full gate output, the predicted discharge of one turbine is 220 cusecs. The turbine casing design pressure is 65 lb. per sq. in.

The wicket-gate operating mechanism for regulating the speed of each turbine and rate of pumping consists of a 2½ h.p. high-starting-torque motor, reduction gears, limit switches, and a handwheel for manual operation. The unit is capable of moving the gates through a complete closing or opening cycle in 20 sec.

Generators

The two generators in the plant are each rated at 6,315 kVA, 95 per cent. power factor, 4,160 V, three-phase, and 60 cycles at 240 r.p.m. Each generator is a vertical-shaft synchronous machine and is designed to rotate clockwise when looking down on the unit. An extension is provided to the stator frame to support the generator and lower bearing bracket, provide access to the turbine pit, and contains openings to admit cooling air for the generator.

A thrust bearing and an upper guide bearing are installed above the rotor. A common oil reservoir is provided for the thrust and upper guide bearing, and there is also a separate oil reservoir for the lower guide bearing. The thrust bearing is a vertical self-equalising Kingsbury type, and is designed to withstand a runaway speed of 480 r.p.m., carrying the entire weight of the rotating parts of the generator, exciter, turbine, and the unbalanced hydraulic thrust of the turbine runners. As the thrust bearing is supported by a bracket consisting of a central hub with steel arm supports from the stator frame, the load above is transmitted successively through this bracket to the stator frame, to the stator frame extension, thence to the sole plate and on into the foundation. The upper bearing bracket also supports the main exciter which is directly coupled to the generator shaft. The lower bracket supports the lower guide bearing and the combination air brakes and hydraulic jacks.

The lower bearing bracket for each generator is so arranged that it can be removed through the stator of the generator. The stator bore and the stator extension opening beneath each generator is designed to permit the installation or replacement of turbine parts.

Main excitation for each of the generators is provided through a direct-connected vertical-shaft shunt-wound d.c. generator mounted on top. The capacity of the exciter is at least 10 per cent. in excess of the actual capacity required to supply the field-excitation current of the main generator when operating at the rated power factor, speed and voltage, and at 115 per cent. of the rated kVA output. The main exciter excitation is supplied from a 125 V battery, and an automatic voltage regulator is provided.

The generators are both open-type air-cooled machines. Cooling air enters the stator-frame extension, circulates through the generators by means of fans on the generator rotors and discharges into the generator room through openings in the stator wrapper plate.

Air-operated brakes are installed to have sufficient capacity to bring the rotating parts to a stop from one-half normal operating speed within 7½ min. after the brakes are applied, without field excitation of the generator. The brakes are also designed for use as hydraulic jacks to lift the generator and turbine rotating parts a sufficient distance to provide for removal or adjustment of the thrust bearings. The jacks are actuated by a hand-operated high-pressure oil pump.

Pumps

Directly connected to each of the pump turbines is a vertical-shaft centrifugal pump having a volute case. Each of the two pumps has a rated capacity of not less than 167 cusecs, under a total head of 108 ft. When the pumps are operating at this head, the warranted efficiency is 85 per cent. The pumps are designed to operate satisfactorily under total heads ranging from 104 to 112 ft. As the pumps are directly connected to their turbines, the speed of the pumps is always the same as the turbine speed and is varied by changing the turbine wicket gate opening. Rated discharge for each pump is expected at about 425 r.p.m. The pump-casing design pressure is 110 lb. per sq. in.

The pumps are located above the turbines and have shafts connected by a flanged coupling, and receive water through their individual intake pipes. To provide the most efficient and economical building layout and piping arrangement, the suction of the pumps is on top. This inverted position of the pumps creates an unusual condition in regard to the hydraulic thrust of the units carried by the thrust bearings in the pumps. The pump thrust acts upward, and the turbine thrust acts downward. Both thrusts increase with speed, but the net downward thrust is reduced as the speed increases. The upward pump thrust is, of course, increased when shut-off pressure is produced by pumping against a closed discharge valve.

In the event of the pump speed approaching about 420 r.p.m. when a discharge valve is closed, the net hydraulic thrust would be upward and could raise the two rotors and shafts off the thrust bearing. To assure that this condition does not occur, an operating procedure has been developed which instructs the operator, through nameplates on the unit instrument panel, to limit the turbine wicket-gate opening, keeping speed below 375 r.p.m., unless the pump discharge valve is open. The nameplates also indicate that the pump discharge valve should not be closed unless the speed is below 375 r.p.m. The 375 r.p.m. speed, recommended by the pump manufacturer, is the approximate speed required to prevent back flow. A pressure switch in the pump casing, electrically interlocked with the wicket gate and discharge valve motors, is provided to guard against improper operation.

Each pump discharge line is provided with an electric motor-operated gate valve. The valve is suitable for throttling and shutoff, although it will normally be either fully open or closed. The electric motor is rated at 5·7 h.p. and is capable of making a full valve closure in 3½ min.

Discharge Line

Connected to the steel discharge manifold and emerging from the left side of the plant is the dis-

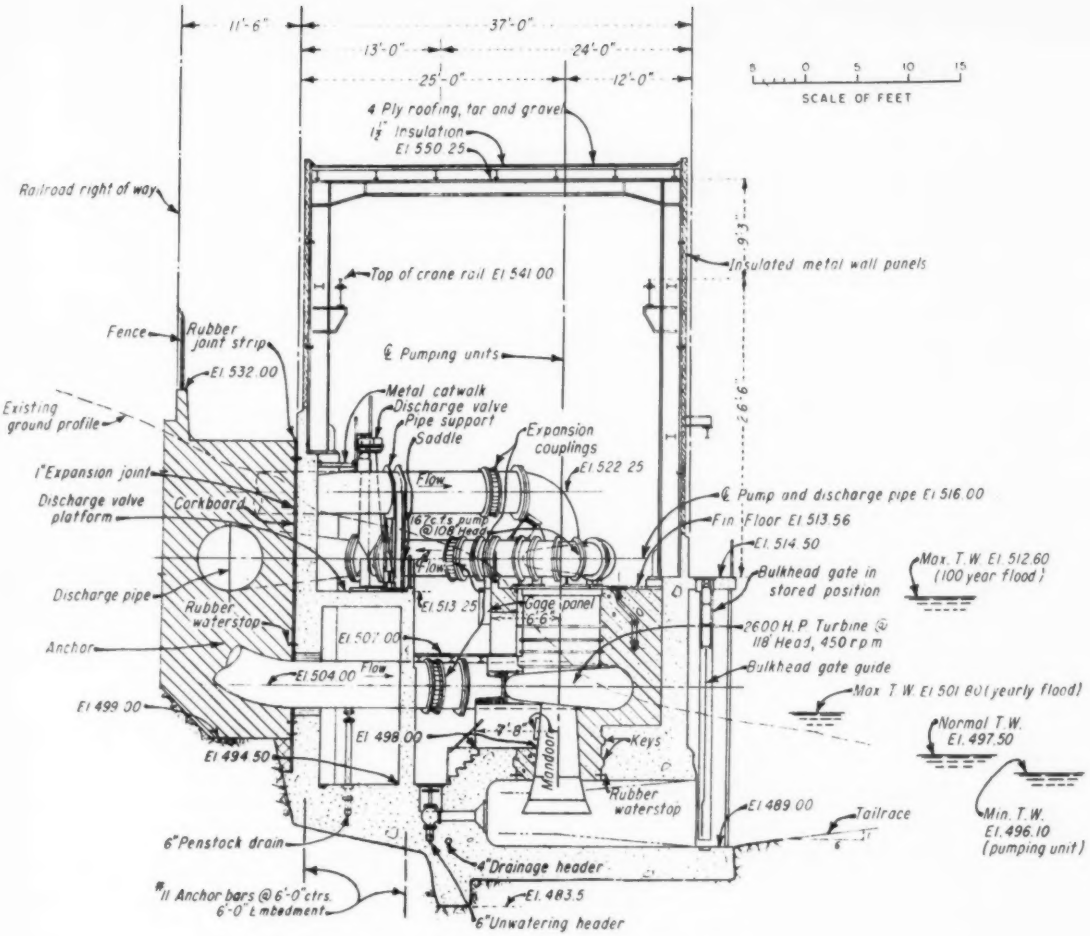

Fig. 5. Section through one of the pump units

charge line, 3,400 ft. long, which drops down to the north side of the Yakima River, crosses the river as a 500 ft. long submerged conduit, about 10 ft. below the river bed, and emerges on the south side where it terminates in an outlet structure and transition to the Main Canal. The initial section of the line as it leaves the plant is a 90 deg. elbow which has a combined bend to accommodate the sharp 45 deg. downward slope to the north bank of the river. The elbow, about 100 ft. long, is a steel conduit having an inside diameter of 99 in. and a wall thickness of $\frac{7}{16}$ in. It is encased in a concrete anchor.

From the elbow section, the discharge line for a distance of 2,300 ft. is built in sections of reinforced-concrete pipe having an inside diameter of 99 in. and a wall thickness of 9 in. The 2,300 ft. reach is lined with a welded-steel plate liner, $\frac{5}{16}$ in. thick, for the initial 400 ft., $\frac{3}{16}$ in. plate for the following 360 ft., and $\frac{1}{8}$ in. plate for the remaining 1,540 ft. The following 1,000 ft. of the discharge line is of the same construction and cross-sectional dimensions, except that the plate liners are omitted.

A blow-off and manhole structure housing a 6 in. blow-off pipe is located near the plant and can be reached from the plant over a bridge 30 ft. in length. The discharge line can be unwatered by the blow-off pipe, the pumps being used to complete the unwatering after the flow by gravity has stopped.

About 600 ft. upstream from the outlet transition, provision has been made in the discharge line for the temporary installation of brine-injection equipment, together with two electrodes, spaced 140 ft. apart, to aid in determining the discharge by the salt-velocity method.

A turbulator will be installed about 30 ft. upstream from the first electrode to ensure proper mixture of the water with the brine solution. A propeller-type meter housed in a meter structure located about 120 ft. from the outlet of the discharge line will be permanently installed for operational purposes. The salt-velocity equipment will be used to calibrate the permanent meter. For maintenance, the meter can be removed from the structure without stopping the flow in the conduit. The outlet structure of the discharge line consists of a round-to-square transition, an air shaft, a flap gate, and an open transition to the Main Canal. The flap gate has been provided to prevent backflow in the event of a power failure and to prevent the entry of gravel, rocks, and other debris during the non-irrigation season.

Fig. 6. Forebay and headworks, showing, left to right, ice sluice, wasteway siphons, three pump intakes, and two-power-penstock intakes

Switchyard

The switchyard is located in a confined area adjacent to the plant building and between the Union Pacific Railroad right-of-way and the river. Its principal features are the main power transformer and a line take-off structure equipped with an air switch and automatic ground switch. The output of the two generators is matched and supplied to the Bonneville Power Administration's 115 kV transmission line between Grandview and Richland by means of this transformer. No provision for future units or increased capacity has been made.

The transformer is rated three-phase, 11,200 kVA self-cooled; it has a forced-air rating of 14,000 kVA. The voltage ratio is 4,000 V delta to 115,000 V earthed star. Each high-voltage bushing is equipped with one 97,000 V lightning arrester.

The air switch is of the horn-gap type, and is mounted 60 ft. above the ground on the line take-off structure. It is three-pole single-throw and is rated 115 kV, 600 A. This switch is equipped with an electric-motor operating device for use on 125 V direct current. The earthing switch is two-pole manually wound automatic high-speed spring-closed, operating on 125 V direct current, and operates on the clip end of the air switch.

There are no overload interrupting devices such as fuses or circuit breakers in the incoming 115 kV line. The purpose of the earthing switch is to protect the power transformer for feedback from the Bonneville Power Administration system. Any fault from the high-voltage terminals of the transformer to points past the generator breakers is cleared by relays that trip this switch, which earths two phases of the Grandview-Richland line, immediately de-energising that line by tripping out the Bonneville system breakers and eliminating any further feed from that source.

No coupling capacitors, potential devices, or potential transformers are used on the 115 kV side of the transformer, as all potential for relaying and synchronising purposes is obtained from potential transformers on the 4,000 V busbars.

Construction

Construction of the Chandler power and pumping plant and its appurtenant works began in July, 1953, under a $1,957,712·90 contract awarded to the A. J. Cheff Construction Company of Seattle, Washington. This contract is virtually completed. A second contract for the completion of the plant was started in May of last year. The completion contract, which includes among other items of work the installation of machinery and electrical equipment in the plant, switchyard, and headworks, was awarded to the Western Electrical Construction Company of Portland, Oregon, on its bid of $158,000.

Under the provisions of the specifications for construction of the plant, alternative bids were invited for construction of the power penstocks and intakes and for the discharge line. The alternatives to the concrete pipe construction, which was awarded to the contractor on the basis of his low bid, were steel-pipe penstocks and pump intakes and a steel-pipe discharge line crossing the Yakima River over a series of concrete piers. The low bid for construction of the concrete penstocks and pump intakes was about 24 per cent. less than the low bid for the steel-pipe penstocks and pump intakes. The low bid for construction of the concrete discharge line was about 12 per cent. less than the low bid for the steel pipe line.

Construction of the major portion of the Chandler Canal—a 7·8 mile reach—was completed in July, 1954, under a $1,613,279 contract awarded to J. A. Terteling & Sons, Inc., of Boise, Idaho.

The initial 2·3 mile section of the Chandler Canal comprises the old Prosser Canal which begins at the Prosser diversion dam. This section is now being enlarged to accommodate the new design flow of 1,500 cusecs required for diversion to the Chandler Plant. Under the same contract for enlargement of the Prosser Canal, the contractor, Paul Jarvis of Wenatchie, Washington, is altering the Prosser diversion dam. This $420,612·80 contract, started in May, 1955, includes raising the overflow crest of the dam by 1·5 ft.; enlarging the existing headworks from 1,100 to 1,500 cu. ft. per sec., removing the existing fish ladders at the centre of the dam, constructing two new fish ladders, and making other improvements to facilitate the passage of fish at low flows. (Protection of runs of migratory fish diverted through the dam's fishway facilities from the Yakima River was an important consideration in the development of the Kennewick Division.)

In 1932, the Bureau of Reclamation placed the Prosser power plant in operation. This 2,400 kW plant, near the Prosser diversion dam, operated on a 43 ft. head. The Chandler power and pumping plant will operate under a power head of 118 ft., as compared to the 43 ft. head at the Prosser plant. Accordingly, the older plant was taken out of commission in May, 1955, and will be dismantled.

Across the Yakima River, three contracts are in force for construction of the Main Canal. The initial 2·2 mile reach of the work was completed in November, 1954. With the initial section and the completion of the work in progress, the canal will be brought to its full length of 42 miles.

Personnel

Design and construction of the Chandler power and pumping plant are under the general direction of Mr. L. N. McClellan, Assistant Commissioner and Chief Engineer of the Bureau of Reclamation, whose offices are in Denver, Colorado. The technical phases of operation and maintenance of the installation will be under his general direction also. Mr. W. A. Dexheimer is Commissioner of the Bureau of Reclamation; his offices are in Washington, D.C. The Yakima project is in the Bureau's Region 1, which is under the direction of Mr. H. T. Nelson, Regional Director. Mr. O. W. Lindgren is Superintendent of the Yakima project at Yakima, Washington. Mr. W. L. Karrer is Construction Engineer of the Kennewick Field Division at Kennewick, Washington.

Elevating Grader Attachment

Blaw Knox "Super 12" motor grader with elevating attachment

A new attachment now available from Blaw Knox Limited will convert their well-known "Super 12" motor grader into an elevating grader which can load spoil into dumpers at rates up to 750 cu. yards per hour or cast at rates up to double that figure.

The elevating grader attachment comprises a conveyor with a continuous 42 in. wide belt, driven from the engine crankshaft, and running over roller idlers spaced 1 ft. apart. Spoil is fed directly to the belt by a 30 in. plough disc made from heat-treated carbon-manganese steel. The basic length of the conveyor is 15 ft. and standard extensions enable conveyor lengths of 18, 20, 23 and 25 ft. to be obtained. The discharge height is adjustable, the conveyor being lifted and lowered by power-controlled cables.

The BK "Super 12" motor grader, fitted with the new attachment, is ideal for roadmaking and widening work and will strip down to sub-grade and build up road surfaces for final grading; it can be used for terracing operations; it will cut drainage ditches and load spoil on to trucks in one operation; or it can side-cast spoil to make a new formation. Loading and casting, of course, are the primary functions. All controls are located in the cab and, it is claimed, one operator will keep a fleet of trucks or dumpers continually on the move.

Cutting a Large Relief Channel

On the "South of Magdalen Bend" section of the relief channel for the Great Ouse River, Norfolk, Sir Robert McAlpine's earthmoving team have achieved some remarkable output figures. Since the job was started on June 5, 1955, a quarter of a million yards of earth have been moved, 172,000 by the scrapers and the remainder by drag-lines.

The scraper team now consists of an Allis-Chalmers HD.21, an HD.20, and two HD.19's, all pulling 20 cu. yard Onions scrapers. An Allis-Chalmers HD.20 fitted with a Gar Wood hydraulic angledozer is used for push-loading and general site work. McAlpines had only recently added one of their HD.21's to the scraper team on this site and it was interesting to watch this machine working side-by-side with its predecessors, the HD.19's and the HD.20's. The greater power of the HD.21 was obvious both in the cut and when travelling to and from the tip. While excavating in Kimmeridge clay on a sloping cut to the bottom of the channel, with a round trip of 1,000 yards, including the climb out of the cut and up the bank, the HD.21 made four trips for every three made by the HD.20.

The excavation of the relief channel will take five years. It will be 200 ft. wide on its bed, about 300 ft. wide at ground level, and 23 ft. deep. Although it will run from Denver to King's Lynn it will not be possible to use scrapers north of Magdalen Bend since the land is almost 100 per cent. soft silt. A large proportion of the excavation south of this section will be by scrapers, and, provided that the weather is not abnormally bad, the work is expected to be completed well on schedule.

FIAT 55LI Tractor

A heavier-duty version of the Fiat crawler tractor, Model 55L, has recently been announced by Mackay Industrial Equipment Limited, Feltham, Middlesex. This new crawler tractor will be known as the Fiat Model 55LI and it incorporates the results of experience gained with the Fiat 55L in all parts of the world.

The Fiat 55LI has the following new features: a

completely cased-in front idler of greater diameter and rim width than that of the Fiat 55L, a larger area of ground contact, there being one more shoe per track than on the 55L, and new counterbored interlocking-type track links. Also, the track frame is braced internally for greater strength, the track rollers are fitted with bellows-type seals, the mounting and the guides of the idlers are improved and reinforced, as has been the mounting of the track recoil springs. Sprocket guards are fitted and track roller guards are reinforced. The track support rollers are of single-body type. The fuel tank is of heavier-gauge sheet steel and the side fenders are of 9 mm. steel plate. Bellows-type shock-proof water-temperature and oil-pressure gauges are fitted.

The Fiat 55L has a high drawbar pull and low ground pressure, making it suitable for heavy and wet conditions. Many of the improvements incorporated in the Fiat 55LI are designed specifically to make its performance and endurance in these conditions even better than that of the 55L.

The BEAMA Dinner

The Annual Dinner of the British Electrical and Allied Manufacturers' Association, under the presidency of the Rt. Hon. the Viscount Chandos, who is the President of BEAMA, was an extremely successful occasion. The President devoted a considerable part of his address to a plea for all electrical engineers everywhere to assist in procuring the supply of physicists, professional engineers, research workers, technicians and craftsmen who were needed now and who would be needed in even greater number, as the electrical industry continued on its path towards enormous expansion. He said that the industry unfolded to youth a thrilling prospect, where a young man could carry on his profession in one or other of the electrical companies in good conditions and with vast capital, industrial and scientific resources behind him. He could have the feeling that not only was he advancing the frontiers of human knowledge, but also he was conferring some degree, however small in his own individual case, of human prosperity on mankind as a whole and of his own country and the Commonwealth in particular.

Mr. E. H. Ball, the Chairman of the BEAMA Council, said that it was significant that in the British electrical industry there were approximately 700 separate manufacturing units, and that the average employment was approximately 1,000 each. It might be thought by some that the electrical industry in Great Britain was dominated by the few large firms much in the public eye. This was far from being the case. A very large proportion of British electrical strength lay in the many small specialist companies, compact, efficient and always ready to seize on new opportunities in the vast expanding field of electrical applications and development. Indeed, he continued, many of the small members of BEAMA set the target for the large units, which made the latter struggle hard to devolve ever greater responsibility and authority on to their "Battalion Commanders." He thought that there might be a lesson there for the enormous public utilities, who had no such smaller examples to emulate. One of the chief functions of the British Electrical and Allied Manufacturers' Association was to create friendship and goodwill between the very large number of industrial units making up the electrical industry in Great Britain. He thought it was true to say that due to the good work done by BEAMA and its affiliated societies the industry was really friendly and co-operative throughout.

Group Captain the Hon. Sir Thomas White, K.B.E., D.F.C., V.D., F.R.G.S., the High Commissioner for Australia in London, replied to the toast of the guests, and in the course of his speech he said that he wished to pay a tribute to the achievements, success and development of this immense industry, and to its quality and efficiency. He said that BEAMA had done a great deal to foster the wide co-operation and publicity within the industry which had resulted in extending British sales and prestige throughout the world.

Surge Tank Stability

A paper entitled "Stability of Parallel-Branch and Differential Surge Tanks" has been presented for written discussion to the Institution of Mechanical Engineers by O. C. Zienkiewicz, B.Sc., Ph.D., A.M.I.C.E., and written contributions are invited not later than February 8. The paper presents a mathematical theory of stability of small oscillations in surge tanks of the type where two water surfaces are present. The name "parallel-branch" surge tank is coined to describe such a system, and it is shown that results for orifice and differential surge tanks can be obtained from it.

On the assumption of ideal governing and small oscillations of flow and water levels, equations giving the limits of stability are deduced for all cases. It is an easy matter from these to test the stability of any particular design by inserting appropriate numerical values.

In general, the results confirm the well-known Thoma formula for the case of a simple surge tank and give results identical with those obtained by Professor Escande for the case of an orifice surge tank. For differential surge tanks, the limits of stability are given in an equation covering the area factors of the riser and the outer chamber as well as the resistance factors of the main conduit and orifices respectively. Graphs showing this relation between the above quantities indicate that:

(1) if the combined area of riser and outer chamber is equal to the Thoma area calculated for a simple surge tank, then the system is stable provided the resistance factor of the orifice is below a certain limiting value;

(2) when the above combined area is less than the Thoma area, then, in general, small but finite oscillations of the water level will persist. By suitable choice of orifices the amplitudes of these oscillations can be made negligible.

(3) if the resistance factor of the orifices exceeds the previously mentioned limiting value, then, in general, it is not possible for stability to be achieved with riser areas less than a specified value.

Methods of calculating the frequency and amplitude of permanent oscillations are presented in the paper. The general case of a true parallel-branch system is

best solved numerically, but the results indicate that in all practical cases the phenomenon of finite amplitude oscillations will exist. Attention is drawn, however, to the necessity of considering the period at which instability is possible as, on occasion, this is too short for the assumption of ideal governing to be applicable.

Analysis of Arch Dams

The Institution of Civil Engineers has announced the presentation of an important paper, "The Experimental and Mathematical Analysis of Arch Dams, with Special Reference to Dokan," by Prof. D. N. de G. Allen, Miss L. Chitty, Prof. A. J. S. Pippard, and Dr. R. T. Severn. The design of the Dokan dam was investigated by this team at Imperial College, South Kensington, for Messrs. Binnie, Deacon & Gourley, Consulting Engineers to the Government of Iraq Development Board. The design has been studied by relaxation methods and the results checked experimentally by means of rubber models. As we had to go to press before the paper was read, we must reserve fuller discussion until next month, but from a preliminary study of the paper it is evident that the authors have made an important contribution to the technique of dam design.

Scottish Progress in 1955

Speaking during a recent inspection of the Lawers scheme, of which a brief account is given elsewhere in this issue, Mr. A. A. Fulton, General Manager of the North of Scotland Hydro-Electric Board, said that 1955 had been of special interest because of the number of stations coming into commission. Clachan power station with a capacity of 40,000 kW was put on load early in the year, and Sron Mor and Allt-na-Lairige stations would come on in 1956, the latter utilising for the first time a dam built on the prestressed principle. At Torr Achilty, a second 7,500 kW set was put on load, and at the Errochty station, which would have a capacity of 75,000 kW, the first 25,000 kW set had been commissioned, and the other two sets were being made ready for running. At Finlarig, a 30,000 kW set was nearly ready, and in Glen Garry in Inverness-shire, the Quoich station of 22,000 kW capacity was in operation.

Lower down the glen, the Invergarry power station, which has a high-head Kaplan turbine, was expected to be taking water at any moment, perhaps before the year (1955) was out. The small underground power station in the Mullardoch tunnel had also been commissioned. All told, there had been added already 128,000 kW of plant, with a further 20,000 kW at Invergarry and another 50,000 kW at Errochty nearly ready.

Mr. Fulton also said that 1955 had been unusual because it had been phenomenally dry—a problem not confined to Scotland because it had been shared by Norway and Sweden. Rainfall had been very much lower than that shown by any records available, and had been 10 in. lower for the 11 months of the year than ever recorded, that is 10 per cent. of the average rainfall. This had entailed careful husbandry of water resources and a reversal of the flow of energy from the south to the north. It was necessary to go back 100 years to find something as bad. Lord Cockburn in 1842 had recorded that from April to October, there were 10 rain days. Maybe the figures for 1955 would prove even more spectacular.

Alden Hydraulic Laboratory

An interesting outline of the scope of work undertaken by the Alden Hydraulic Laboratory is given in a pamphlet recently published by Worcester Polytechnic Institute, Worcester, Mass. The laboratory was established in 1894 by the late Professor George I. Alden, who was then Head of the Mechanical Engineering Department, and now provides not only the means for undergraduate instruction and for basic research for advanced students, but also offers facilities for sponsored research.

The laboratory is located on a plot of 250 acres, and the various buildings are supplied from ponds giving heads up to 32 ft. A two-storey main building, a two-storey low-head building and a river-model building form the main premises, but there are various other buildings, two outdoor river-model test slabs, and a rotating boom for meter and instrument calibration.

A special feature is made of model tests for hydro-electric and similar structures, and among the important schemes that have been investigated are the Cabinet Gorge hydro-electric development, the C. J. Strike project of the Idaho Power Company, the Waneta development of the Consolidated Mining and Smelting Co. of Canada Ltd., the Hogback Mountain water-supply dam, and the Littleton hydro-electric development.

Meter calibration forms an important part of the laboratory's work, and investigations have been carried out on the entry of missiles into water for the U.S. Navy since 1942. A smoke tunnel is among numerous other facilities available.

"The Engineer" Centenary

Our British contemporary *The Engineer* has just celebrated its centenary by producing a Centenary Number of truly stupendous proportions. Naturally enough, it records the history of the journal since its inception by Edward Charles Healey in 1856, but the bulk of the Number is devoted to the presentation of 26 articles under the general title of "A Study of Influences on Engineering Advancement, 1856-1956." Each article has been written by an eminent authority in his particular field, and reflects the high technical standard for which *The Engineer* is so justly respected. Copies of the Centenary Number are available from the publishers at 28 Essex Street, Strand, W.C.2, at 15s. per copy.

Messrs. Kennedy & Donkin have pleasure in stating that Mr. H. Headland, M.Sc. (New Zealand), M.I.C.E., M.I.E.E., A.M.I.Mech.E., who for some years has been a senior member on their staff, has been appointed a consultant to the Firm.

Rooster Publicity Announcement. Mr. J. Peers, Managing Director of Rooster Publicity Limited, the well-known industrial-advertising and export-sales promotion consultants, announces that the company has changed its name to J. Peers and Associates Limited, and that London headquarters have been established at Summit House, 1-2 Langham Place, W.1.

Abstracts from the World Technical Press

Calculating Penstock Stability

Since the first appearance of hooped penstocks in hydro-electric practice, manufacturers have calculated their stability on the same basis as non-reinforced pipelines of equivalent constant thickness, also called ideal thickness, proceeding from a mean weighted stress which takes into account the thickness of the shell, the dimensions and spacing of the hoops and, finally, the mechanical characteristics of the materials involved—all this in order to arrive concurrently at predetermined safety factors against bursting and fatigue for both shell and hoops, that is to say for the composite wall of the reinforced pipe. The purpose of this article is to demonstrate under which conditions this can be achieved in accordance with the accepted principles of engineering. In the introduction, the author defines the ideal thickness, and the mean admissible stresses as a function of the safety factors mentioned above and of the rate of self-tension between shell and hoops. Subsequent sections deal with elastic deformations, unit stresses, safety factors, examples of numerical calculation, and the effect of the breaking of a hoop. (Giovanni Mattioli, *L'Energia Elettrica*, Vol. XXXII, No. 3, March, 1955, p. 198, 16 pp., 19 ff.)

Valais Development

On the occasion of the General Meeting of the Schweizerische Wasserwirtschaftsverbandes (Swiss Water Association), held in Sion on July 1, 1955, and concluded on July 2 with excursions to the Grande Dixence and Mauvoisin installations, the undermentioned journal published an abundantly illustrated special issue devoted to the Valais Canton. In addition to descriptions of the Grande Dixence and Mauvoisin developments, and the Gougra and Lienne projects, the following articles are included "Water and Water Power in Valais," by J. Wolff; "Precipitation and Discharge in the Rhone Valley above the Lake of Geneva," by E. Walser; "Glaciation in Valais and its Variation in Modern Times," by Dr. P. L. Mercanton; "Utilisation and Application of Electric Energy in Valais," by Dipl. Ing. F. Kuntschen; "Model Tests for Valais Developments carried out at the Federal Technical University," by Prof. Dr. R. Müller, Dipl. Ing. V. Caprez and Dipl. Ing. E. Bisaz, with an introduction by Prof. G. Schnitter. (*Wasser- & Energiewirtschaft*, Vol. 47, Nos. 5-7, May-June-July, 1955, 88 pp., 97 ff.)

Siphon Design

After having dealt in previous chapters with generalities and discharge, the author discusses the qualities which should combine in a correctly designed siphon: automatic, continuous and accurately repeated operation, fast priming, low priming depth, high discharge coefficient, smooth unpriming, smooth flow to avoid vibrations in the siphon itself and the structure in which it is incorporated, desilting action, no trapping of air, accessibility to all parts for repairs, low initial cost and maintenance charges, and minimum cost of protective structures downstream of the siphon. The article ends with a paragraph on small-scale models and the geometrical, kinematic and dynamic similarity they should achieve to produce reliable experimental results. (N. S. Govinda Rao, *Irrigation and Power*, Vol. 12, No. 2, April, 1955, p. 234, 11 pp., 4 ff.)

NOTE: Other articles of interest in the abovementioned Journal: "Pozzolanas, their use in Mortars and Concretes" (S. K. Chopra & N. K. Patwardhan, p. 253, 12 pp.); "Settlement Analysis and its use in Foundation Design" (Bharat Singh, p. 265, 29 pp., 21 ff., 3 tables); "Vibration Experiments on Hirebhasgar Dam during the working of Siphons Nos. 4 & 10 and the Undersluices" (S. K. Guha, Gurdas Ram and G. V. Rao, p. 305, 19 pp., 12 ff., 2 tables); "Aerodynamic Testing of Scale Models in Hydraulic Engineering" (V. Sethuraman, p. 324, 14 pp., 6 ff., 2 tables).

Investigating Dam Seepage

An account is given of the experiments carried out on a small-scale model of the Serre-Ponçon earthfill dam, over 120 m. in height, planned on the Durance on a very deep layer of permeable alluvium. The final design of the dam project required an exhaustive study of seepage through the structure itself and its foundations. Tests on the three-dimensional model, combined with measurements on site, enabled the ideas accepted at the outset about the homogeneity of the alluvium layer and the free passage of infiltration in contact with the rock to be defined more accurately and corrected. The electrical-analogue method applied to the various parts of the dam proved most helpful. Two results of a general nature but having no connection with the investigation specifically undertaken, are recorded and discussed: a theory on the action of capillarity on filtering flow with a free surface, and a new method of variable-flow computation. The paper ends with a comparison of the two methods of investigation applied, electrical-analogue circuits and model tests, and concludes in favour of the former which is said to produce a greater number of directly utilisable results, more particularly in instances of two-dimensional flow and, once adequately improved, is likely to prove just as efficient in three-dimensional flows. (G. Schneebeli, proceedings of the Société Hydrotechnique de France, published in *La Houille Blanche*, Vol. X, No. A, May-June, 1955, p. 320, 12 pp., 15 ff.)

Val Gallina Dam

Following introductory considerations on the choice of the site and type of dam, the design data of this structure of the Piave-Boite-Maè-Vajont system, as well as the model tests carried out in connection with its project and construction, are reviewed and discussed, proceeding from the studies made for the initial project: stability tests, calculation of horizontal elements, contribution of vertical elements to stability, and assessment of rock deformation. The first model tests, as well as the field investigations of the foundation rock are described and their results analysed. A brief description of the final project (1950) and of its construction (1951-52) is then given, followed by an analysis of the first series of measurements made on the dam itself. The article ends with a survey of the tests carried out in 1953 and 1954 on a new small-scale model of the structure with a view to checking

the static behaviour of the whole dam. (Prof. Ing. Guido Oberti, *L'Energia Elettrica*, Vol. XXXII, No. 6, June, 1955, p. 457, 31 pp., 31 ff.)

Surge-Tank Studies

Continuing his remarkable series of surge-tank investigations, the author returns to the question of superposed oscillations in cylindrical tanks, either simple or throttled. Almost every surge-tank specification includes a provision that the design must take into account the water-level fluctuations induced by either of the two following governing operations, considered separately: (a) closure of turbines running at constant load to reduce discharge from its maximum Q_o to 0; (b) opening of turbines to increase discharge from 0 to Q_o, or from 0 to λQ_o with $\lambda<1$, or from λQ_o to 0, starting from an initial constant load. In most instances, specifications insist that closure and opening must be considered as instantaneous. After reviewing the methods of computation applied, the author, dealing first with the simple cylindrical tank, examines the following cases: Q_o to 0 closure following 0 to Q_o opening; 0 to Q_o opening following Q_o to 0 closure; partial opening following Q_o to 0 closure. The instant is determined at which opening intervenes to bring about by the superposition of oscillations, the maximum rise or fall of the water level in the tank, and the extent of the level variation is also ascertained. The values obtained are then compared with the extreme level fluctuations caused by individual governing operations. The same investigation procedure is applied to throttled surge tanks with optimum throttling for complete closure The graphs accompanying the paper show that superposed oscillations can substantially exceed in amplitude oscillations due to individual governing operations. An account is appended of the discussion which followed the lecture. (L. Escande, proceedings of the Société Hydrotechnique de France, published in *La Houille Blanche*, Vol. X, No. A, May-June, 1955, p. 283, 100 pp., 9 ff.)

Tidal Plants

This is an investigation of the operation of tidal plants under restrictions imposed upon the rate of discharge variation. With a port either upstream or downstream of a tidal power station, navigation requirements restrict the rate at which discharge may be varied to suit the absorption capacity of the turbines. In the case of the Rance project, for instance, the limit fixed by the controlling authority is = 3 cu. m./sec.^{2} (2,700 cu. m. per sec. per quarter of an hour). An easy solution would consist in staggering the starting or stopping of the generating units. In single-cycle operation, the condition of maximum efficiency obtaining at the beginning of the flow, as determined by previous investigation, establishes that, whether starting and stopping are done simultaneously or staggered, there is but little difference in the amount of power generated (less than 0·3 per cent. in the case of the Rance). Besides, the head loss occurring in the last unit started and the first stopped is negligible. In the more complex double-cycle operation, the filling of the basin involves the governing of the turbines and the working of the gates themselves. Theoretically rather intricate, the question can be solved at the Rance plant by means of computations based on four different hypotheses, all proceeding from the running of the generating sets at maximum power. A comparison of the results achieved shows a clear advantage in two of the modes of operation discussed: one in which all turbines of the plant run at maximum power at the beginning, ten being subsequently shut down at a certain stage of the filling of the basin, while, in the other, all the turbines run all the time in accordance, however, with a pattern of operation which integrates the effect of the preceding partial shut-down. (R. Gibrat, proceedings of the Société Hydrotechnique de France, published in *La Houille Blanche*, Vol. X, No. A, May-June, 1955, p. 275, 8 pp., 7 ff.)

Santa Felicia Dam

The Santa Felicia dam, Southern California, is an earth-and-gravel-fill dam less conspicuous by its size than by the problems its planning and construction involved. Located in a deep canyon it has a stream-bed length of 1,030 ft., a crest length of 1,260 ft., a cubage of 4 million cu. yards, and creates a water storage of 100,000 acre. ft. Permeability rates proved much lower than expected but remained satisfactory. Compaction of impervious material is based on a compactive effort of 20,000 ft. lb. per cu. ft. To offset aggregate reactivity in concrete, cement was replaced to the extent of 15 to 18 per cent. in weight with a pozzolan (structural-type concrete in spillway chute walls included), a procedure which substantially reduced costs. The most awkward problem arose out of the vicinity of an active oil field. One well in the reservoir area was purchased and duly plugged off, but the former owner retains the mineral rights and may drill a new well on the reservoir bank. To close off water and oil along the centreline of the dam, a three-stage grouting programme was undertaken in two rows of holes 10 ft. apart. The many oil seeps encountered when the foundation rock was reached, and attributed to reduction of pressure on the foundations by removal of the overburden, were brought under control as soon as the fill pressure was built up by means of dry packing with a heavy neat cement mortar. Actually, many of the seeps had dissipated when impounding was about to start, and the engineers in charge are now convinced that the pressure of the dam will be considerably greater than the pressure causing the seeps. (*Engineering News-Record*, Vol. 155, No. 10, Sept. 8, 1955, p. 43, 4 pp., 6 ff.)

CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

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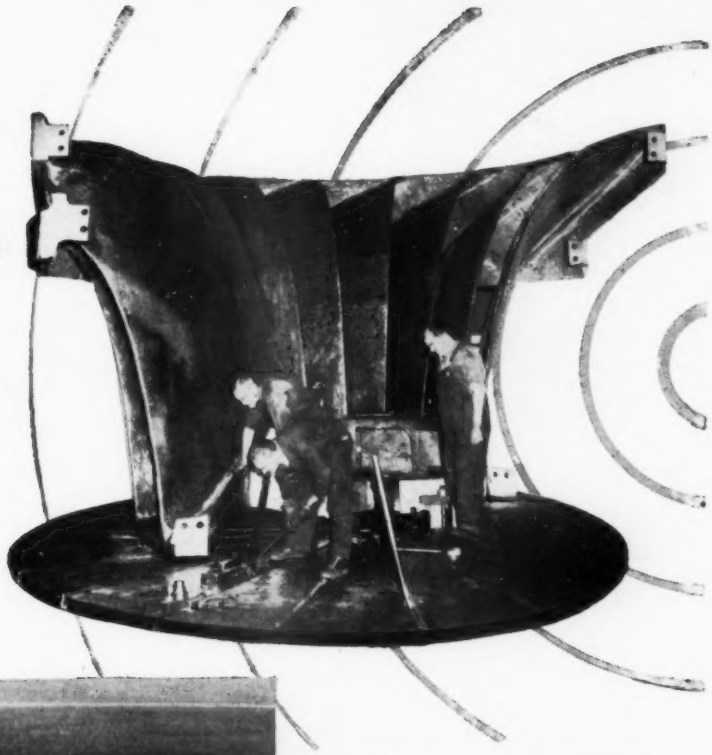

On the St. Lawrence River, between Lake St. Francis and Lake St. Louis, a fifteen mile long canal three-quarters of a mile wide feeds the Beauharnois Power Plant of the Quebec Hydro Electric Commission.

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The photograph of part of the barrage, which diverts water into the headrace tunnel, shows one of the 37′ 6″ span automatic control gates starting to open.

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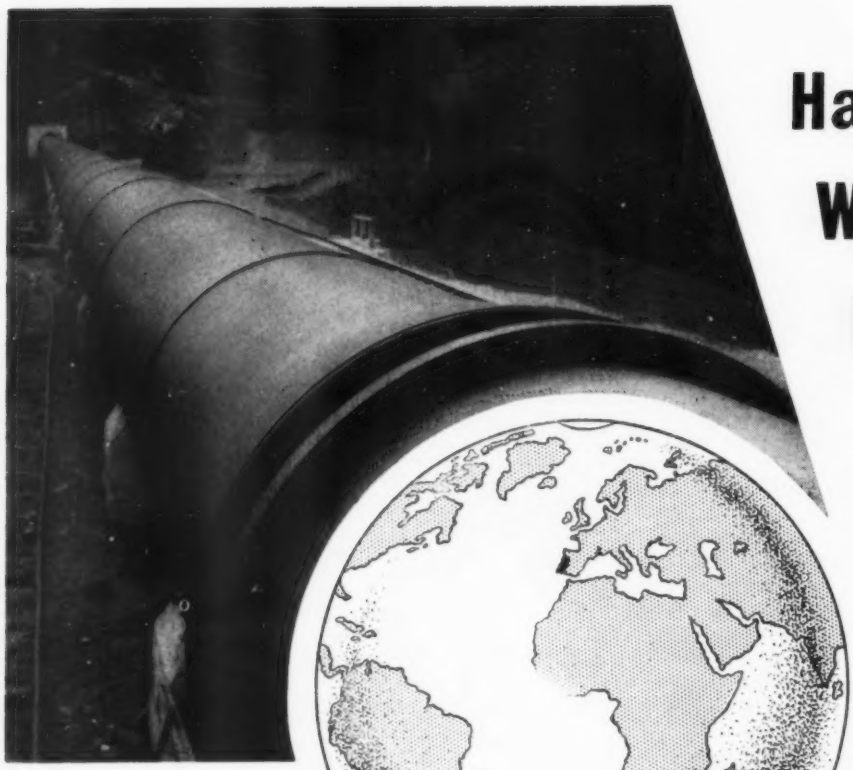

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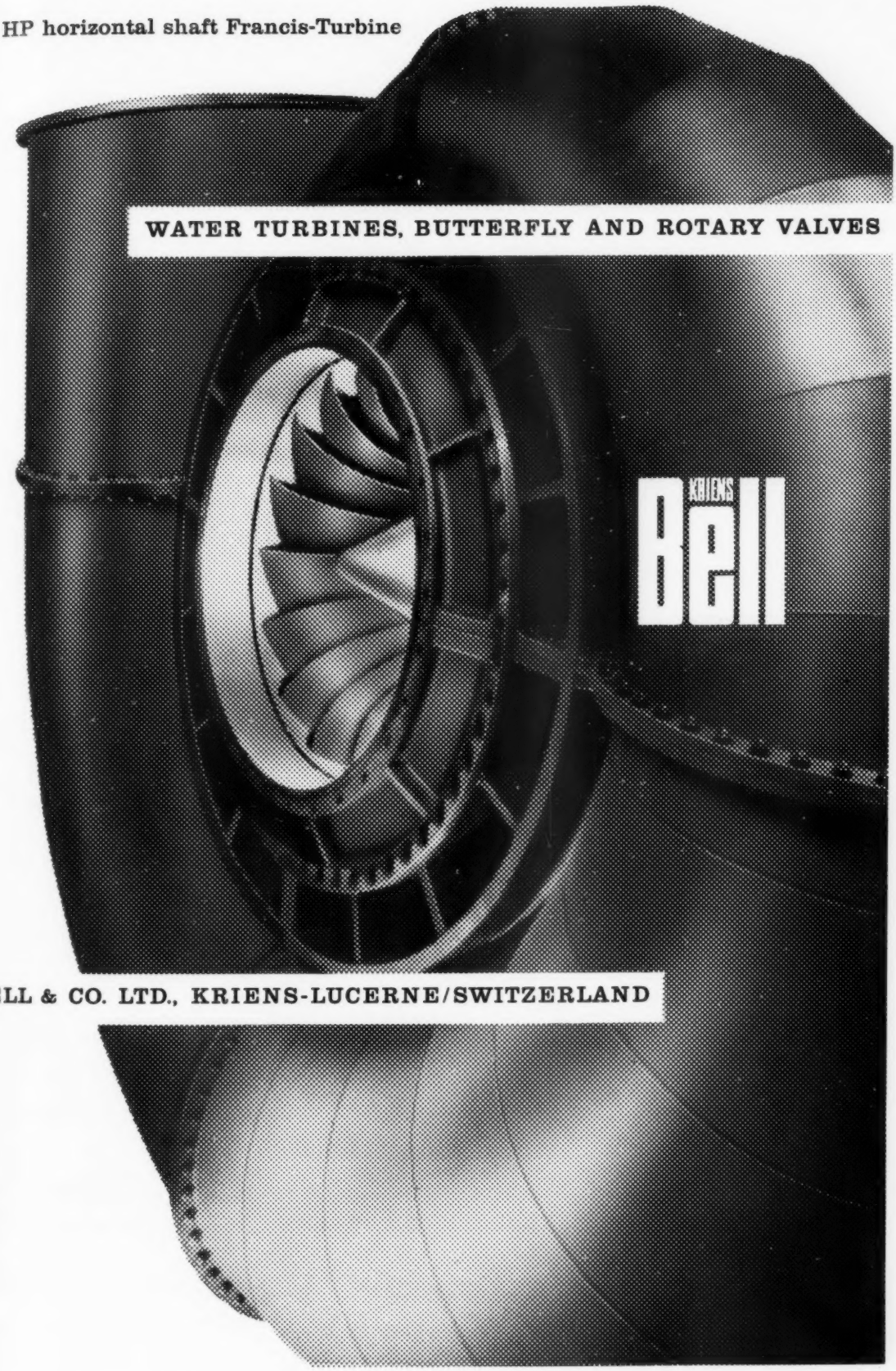

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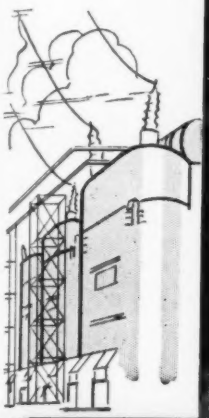

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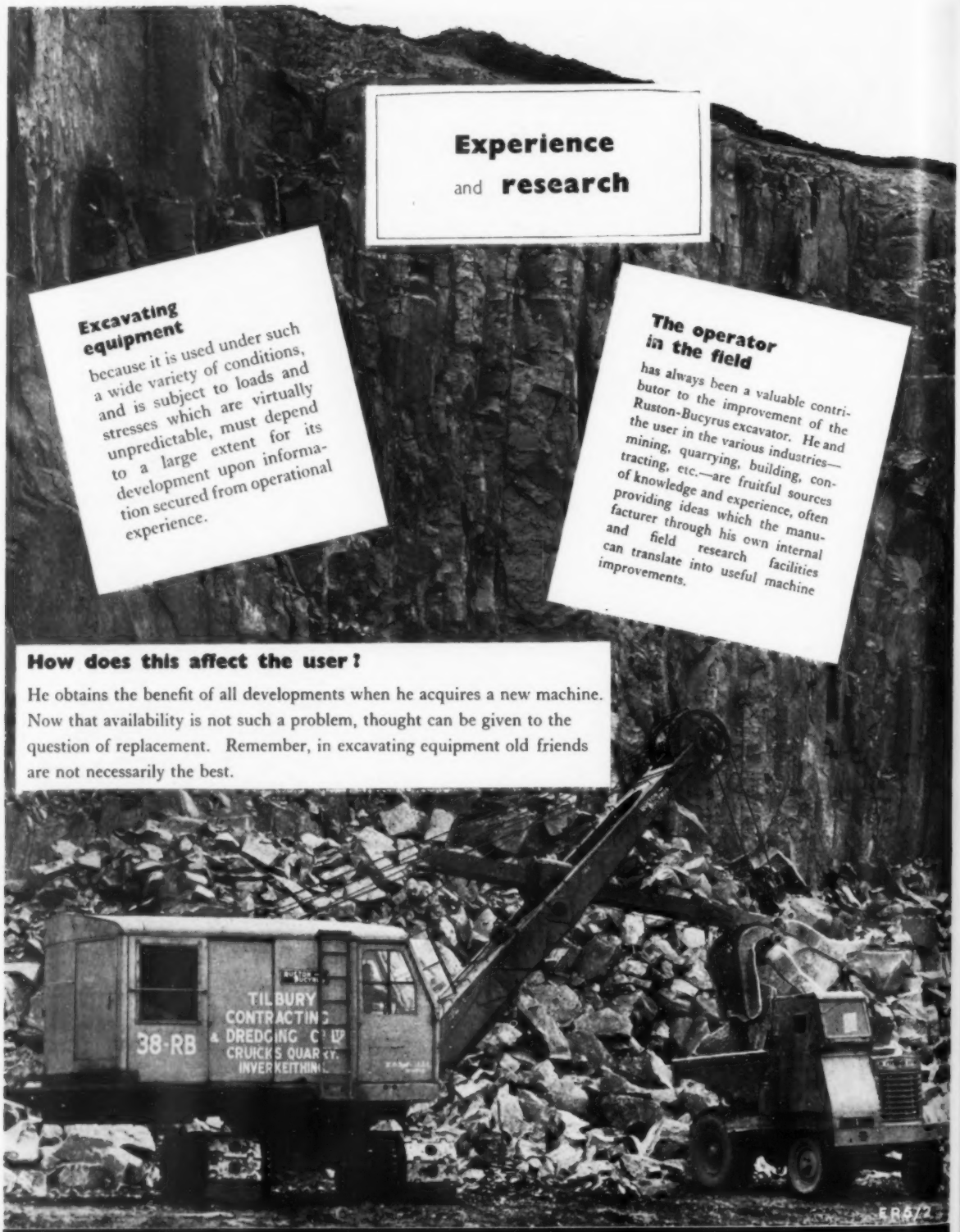

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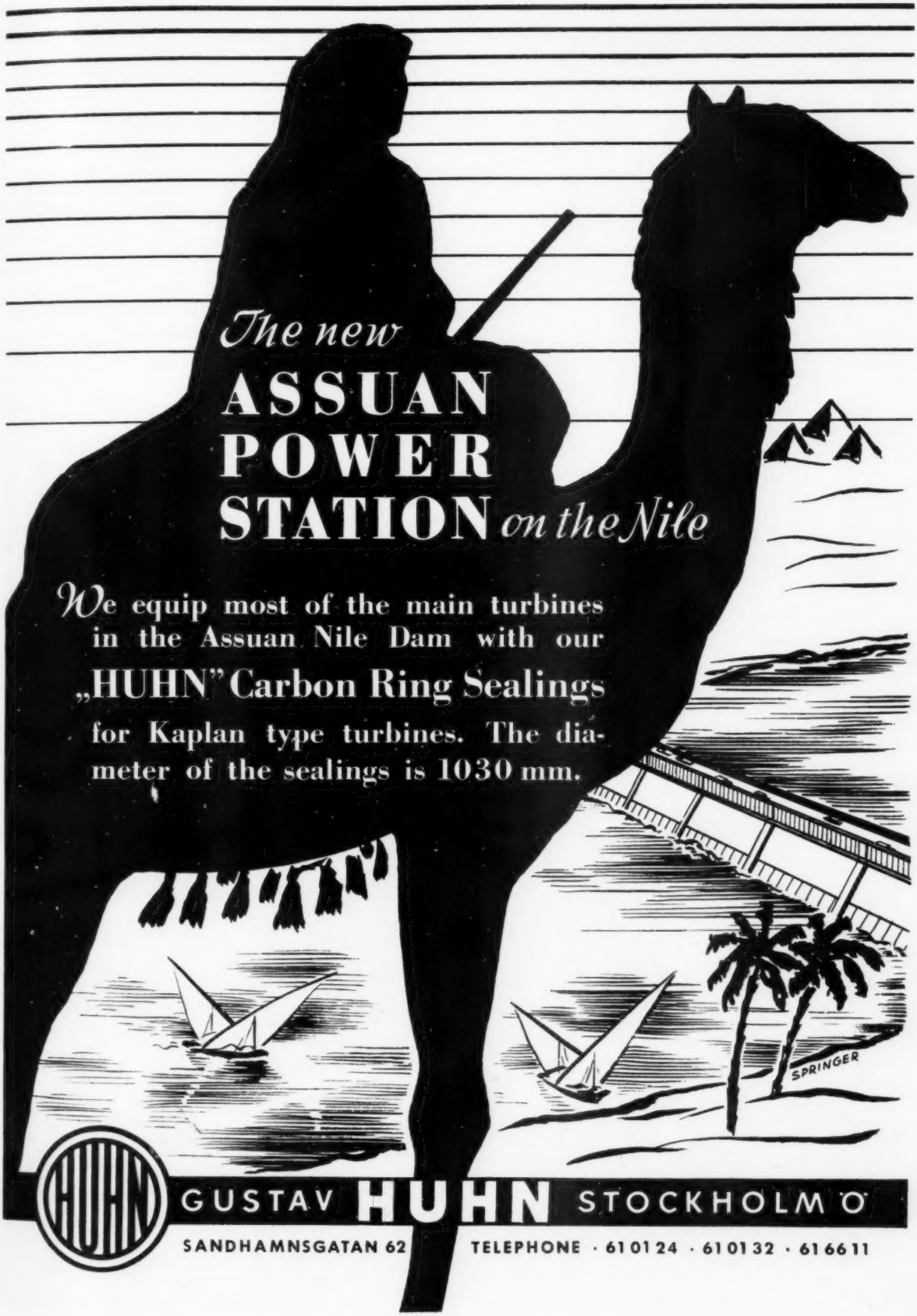

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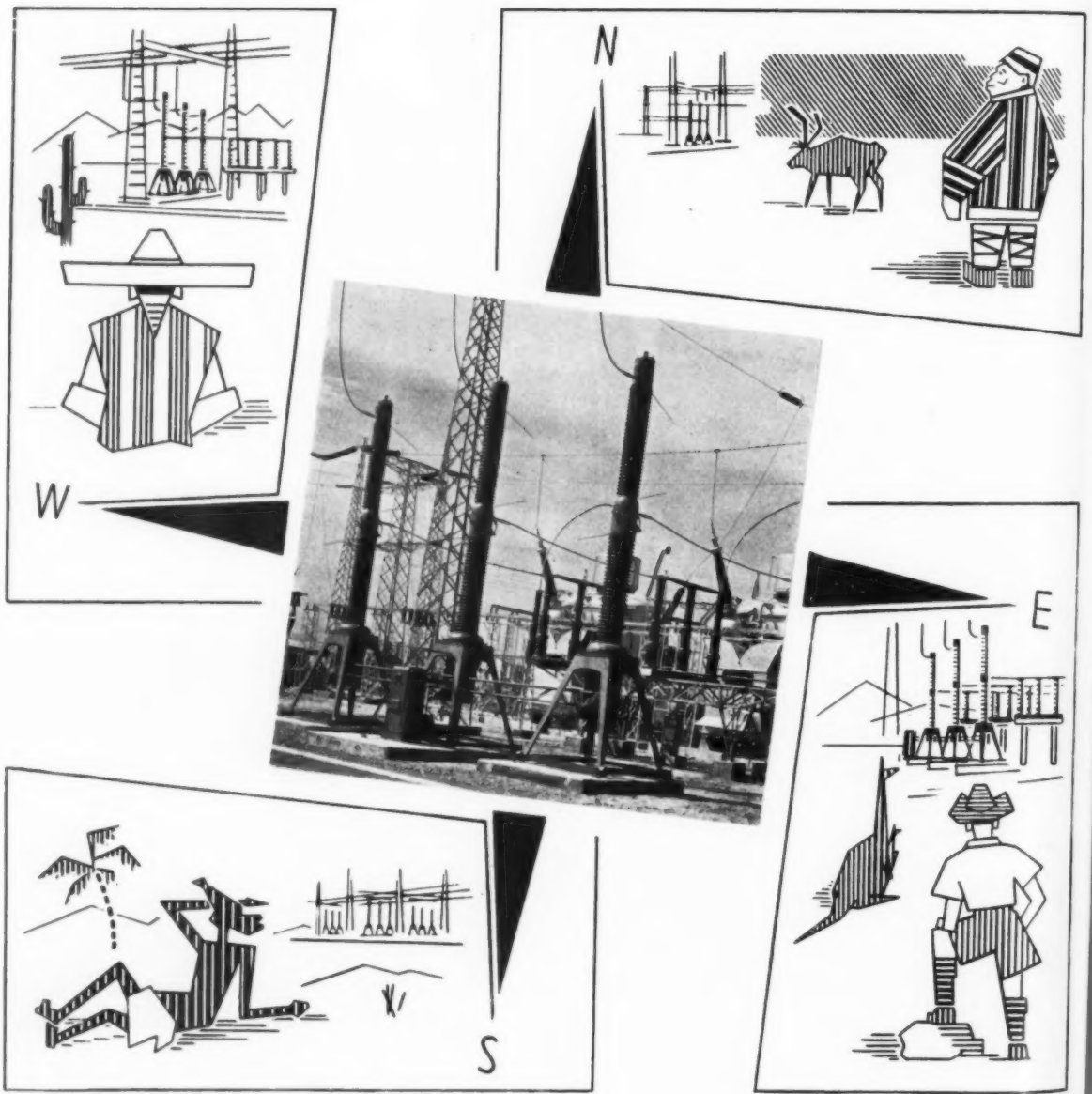

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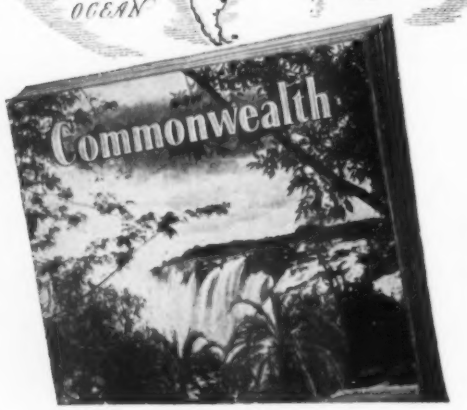

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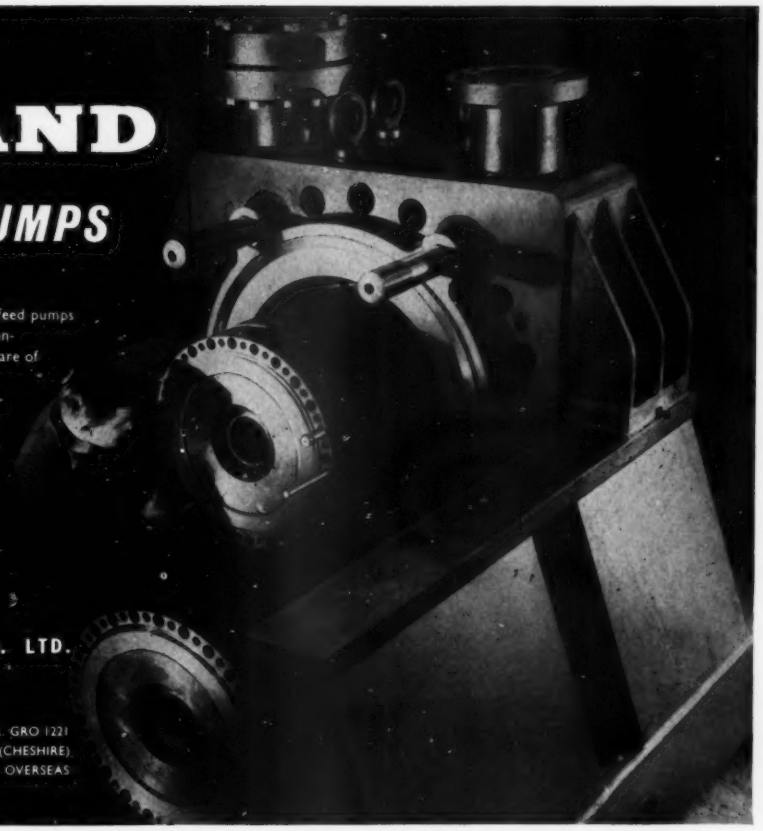

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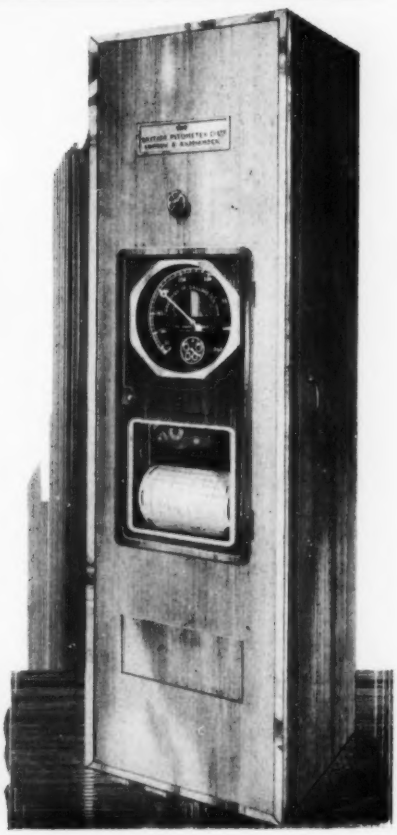

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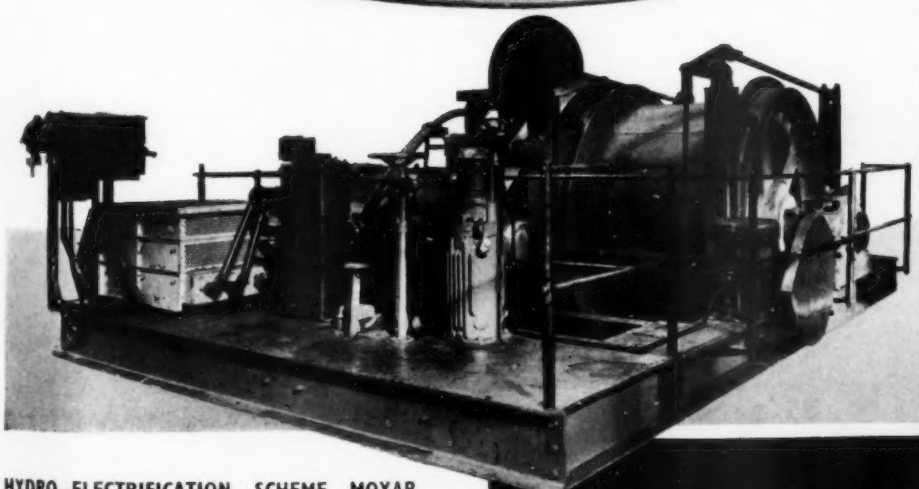

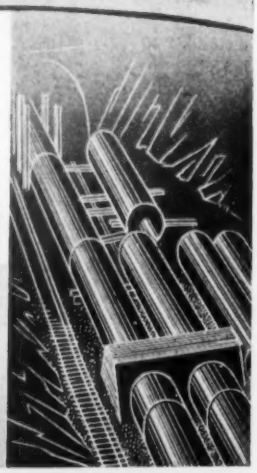

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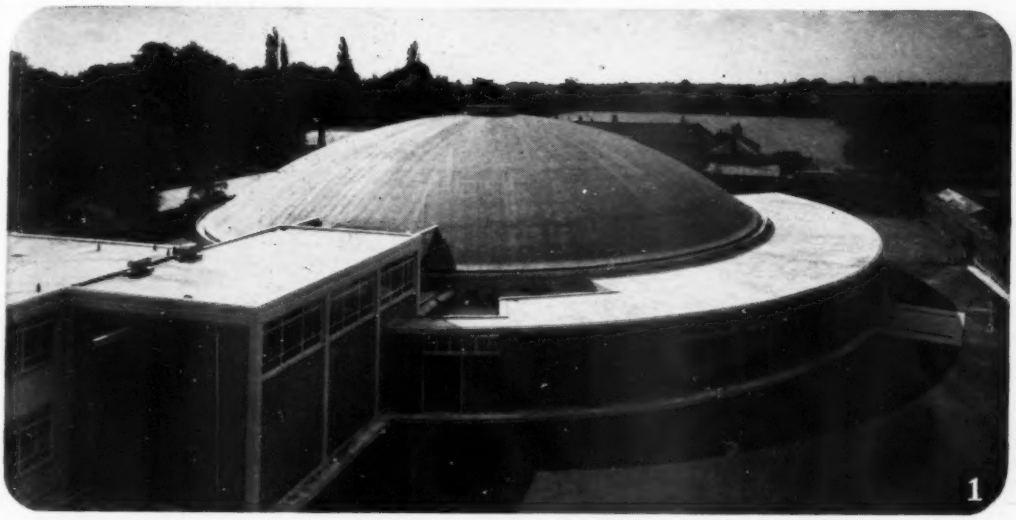
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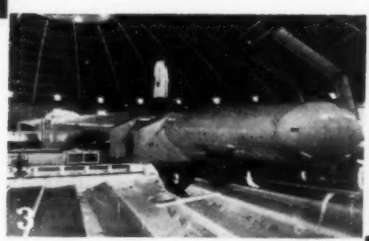
FOR many years Richard Costain Limited have played a major part in British research laboratory construction and were the main contractors to the Ministry of Works, for the Admiralty Research Laboratory recently opened at Teddington. An important item of new research equipment is housed under a domed structure 160 ft. in diameter, which compares with the 112 ft. diameter dome of St. Paul's Cathedral. An annular water channel, below a 60 ton rotating beam, has a capacity of over one million gallons. All the underground reinforced concrete of the walls and tank is gap-graded and pattern vibrated, and designed to withstand water percolation without a waterproofing agent or asphalt tanking.


3

The illustrations show:
(1) The domed structure adjoining the new laboratories.
(2) The annular channel under construction.
(3) Interior view of dome and beam.

Richard COSTAIN Limited

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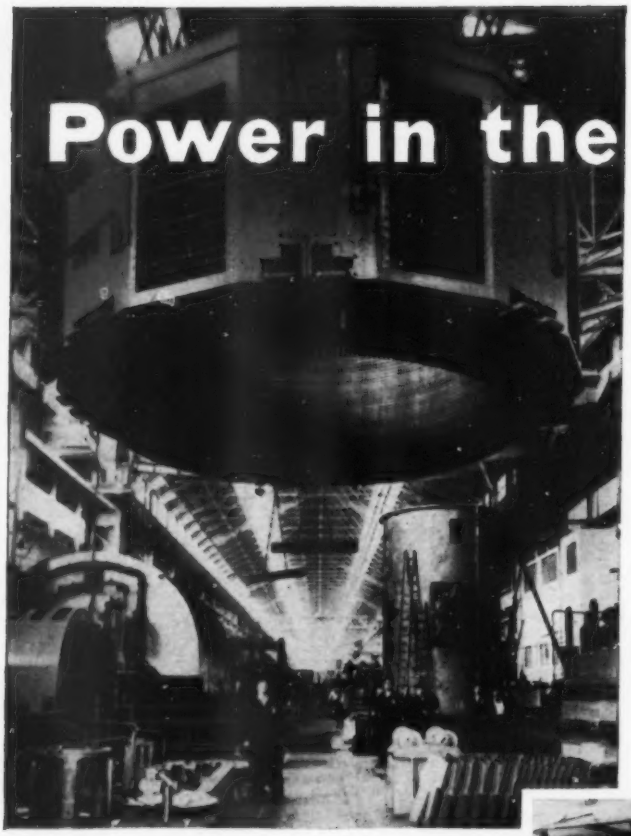
Power in the making...

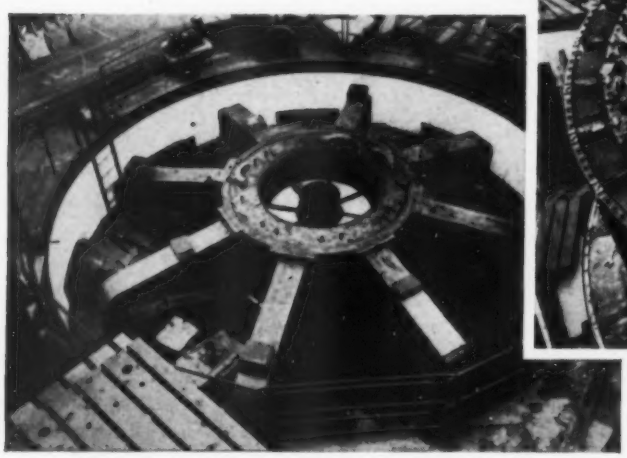


SAN ESTEBAN

A major contribution to Spanish hydro-electric development is the erection of 19 power stations, comprising a total capacity of 845,200 kVA, which are eventually to be constructed for the Salto de Sil, S.A. The electrical equipment for the San Esteban station, the largest of the group, is being supplied by Metropolitan-Vickers. The total capacity for this station will be 300,000 kVA, and the M-V contribution to this consists of four 75,000 kVA A.C. Generators, together with the transformers and switchgear.

Stator of the 75,000 kVA 214 r.p.m. vertical generator. One of four ordered for the station.

The rotor of the 75,000 kVA vertical generator.



Assembly of thrust bearing bracket

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